APRIL 1960
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Incorporated by Royal Charter 1899

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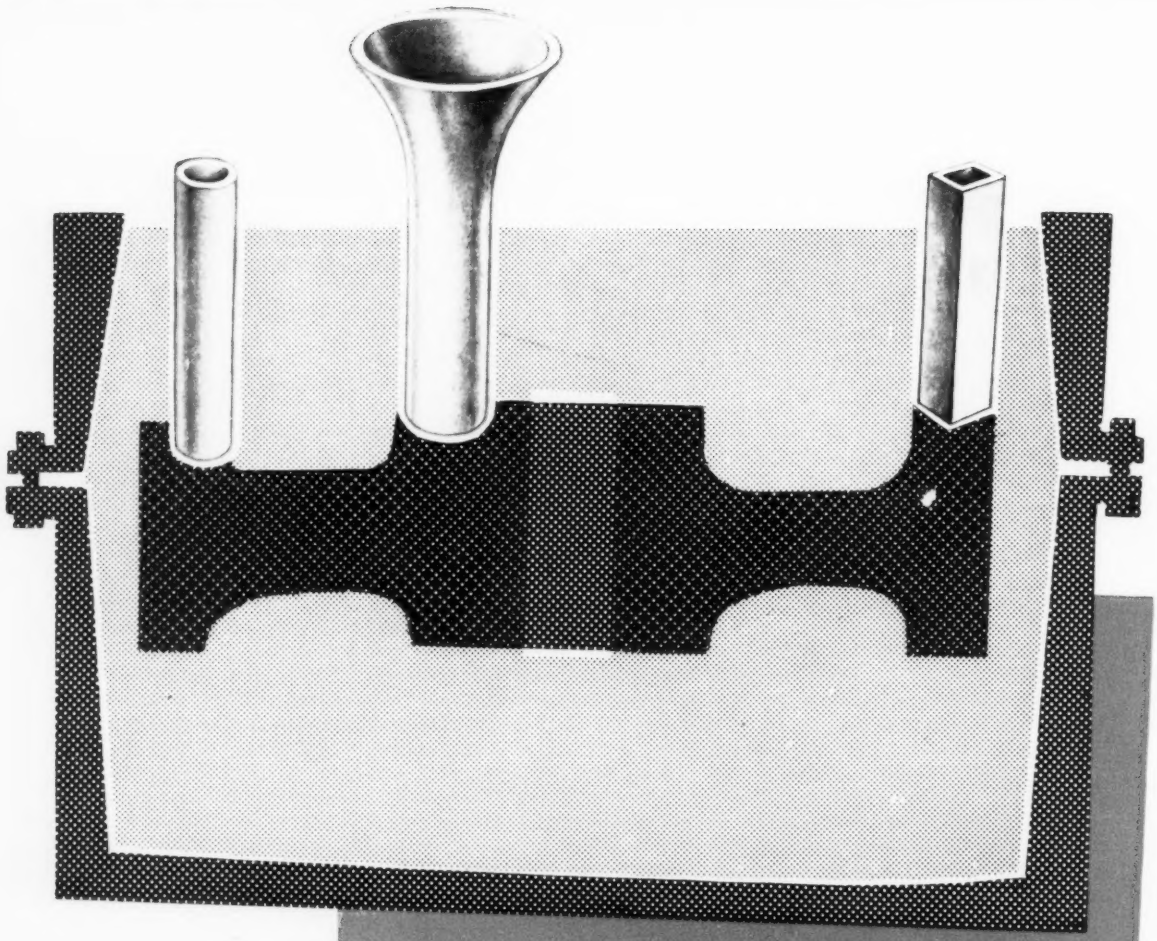

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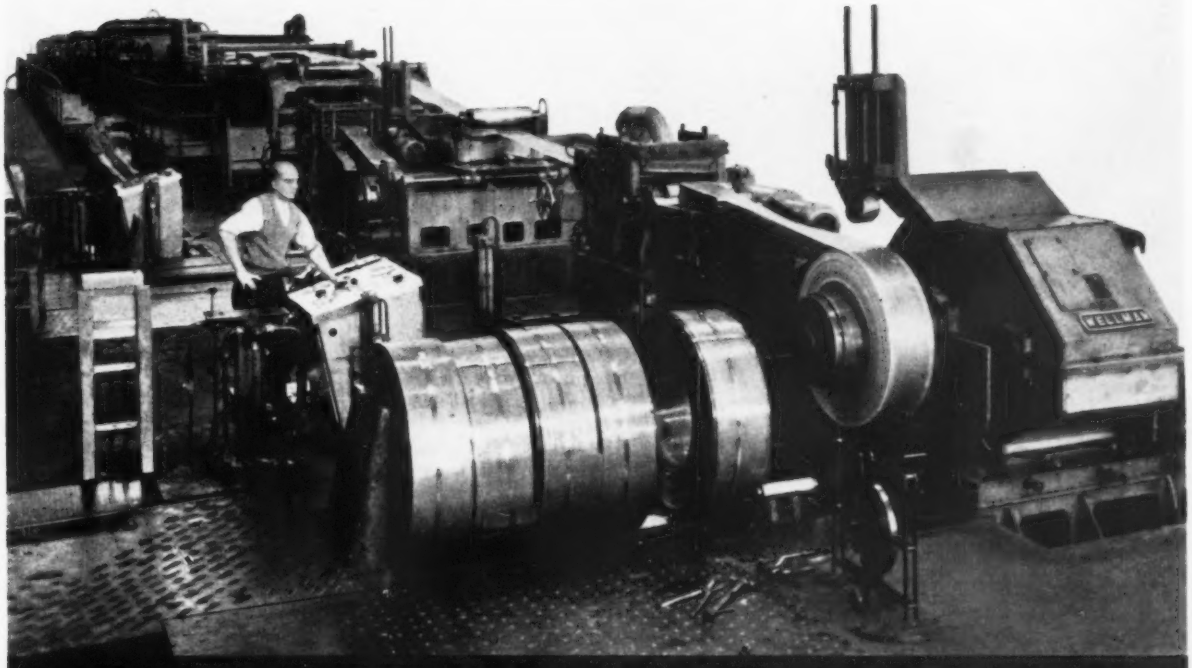

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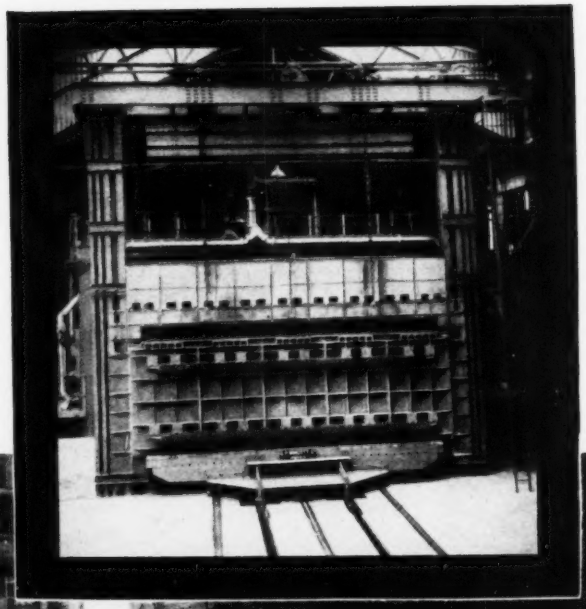

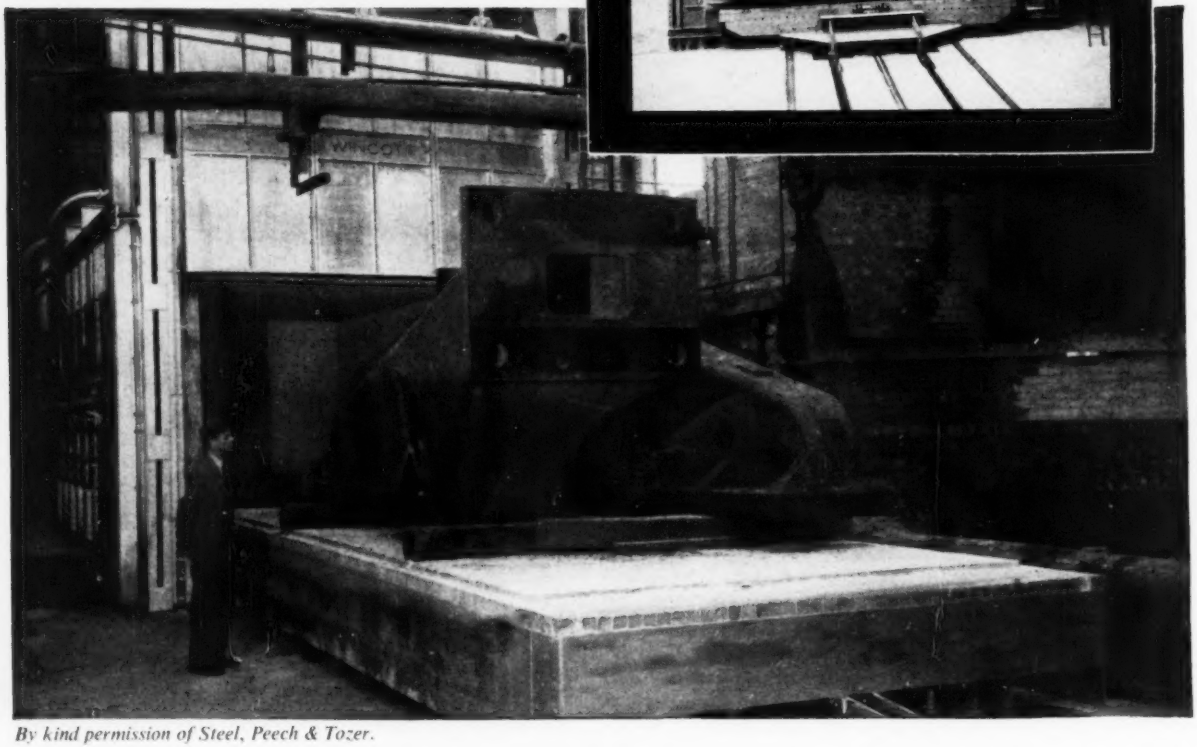

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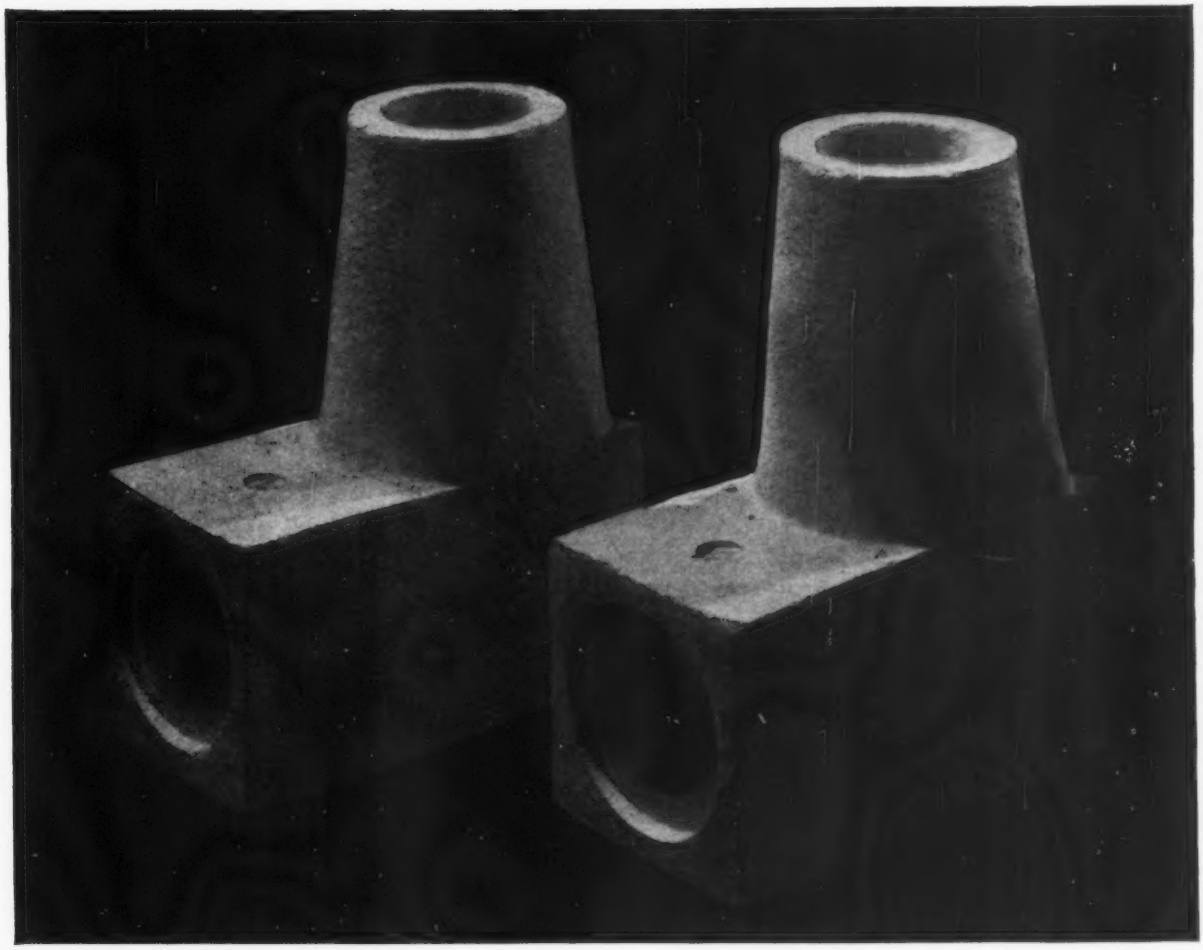

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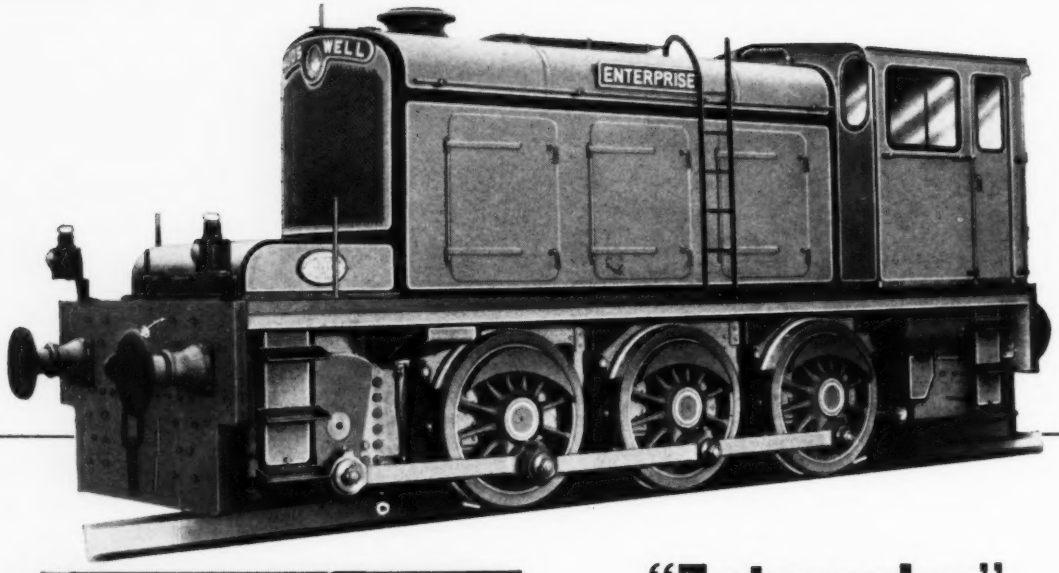

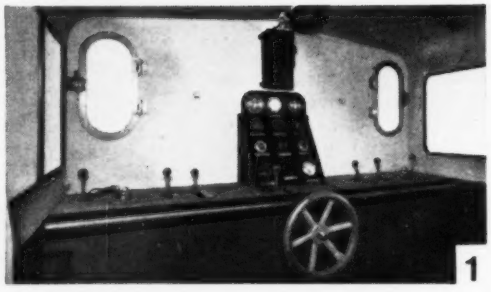

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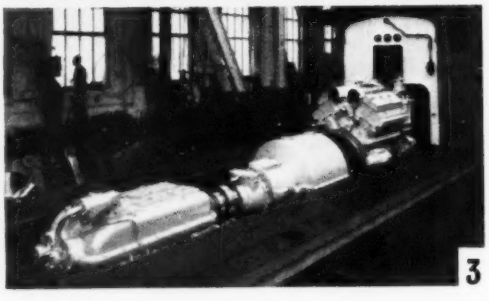

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3. *Installation in the locomotive 'Enterprise' showing left to right, the final reduction gearbox, the Dual Fluidrive transmission, and the Paxman V-6 pressure-charged constant h.p. engine.*

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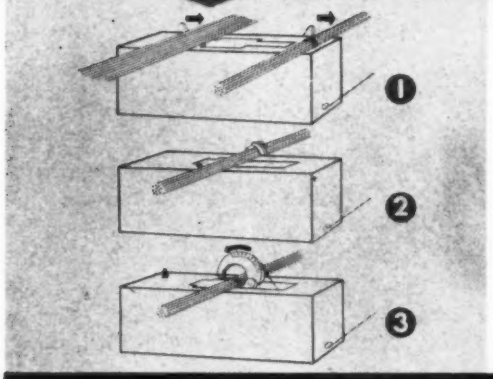

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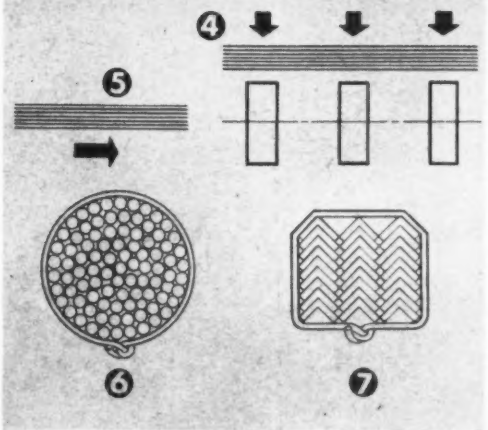

- **receiving the bars, tubes, etc... by lateral as well as longitudinal feed (figures 4 & 5).**
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- **reaching a rhythm of 1000 ties an hour.**

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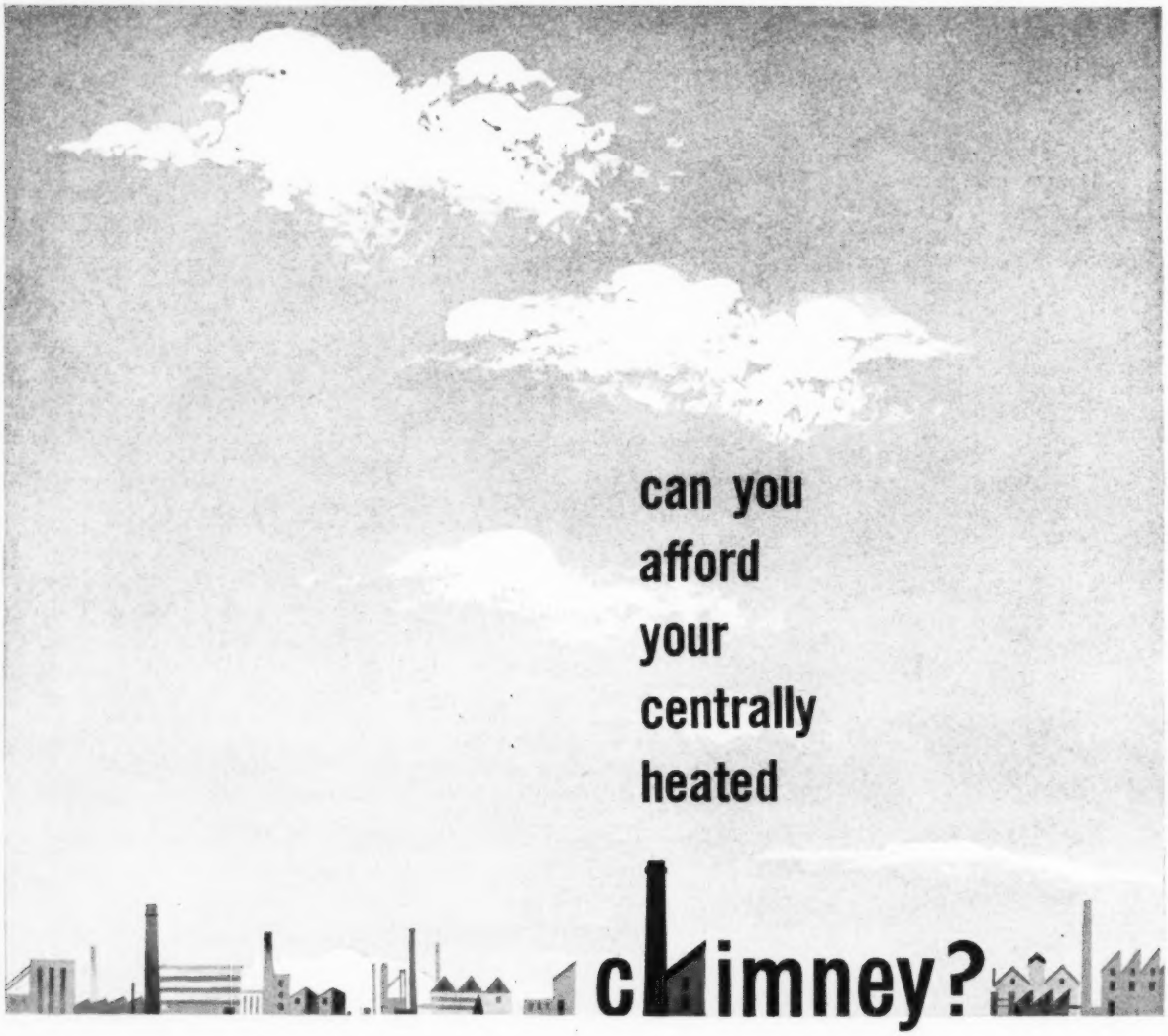

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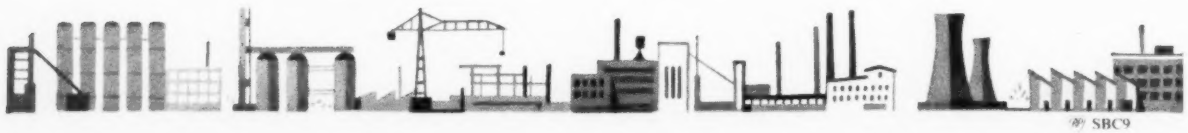

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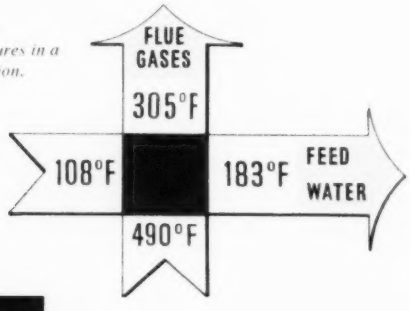

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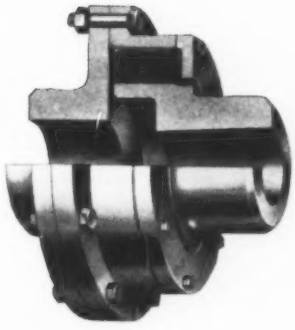

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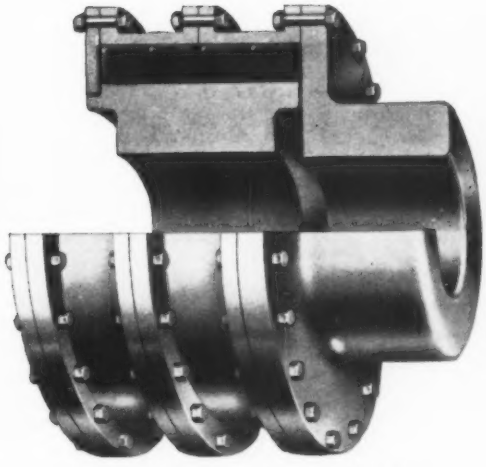

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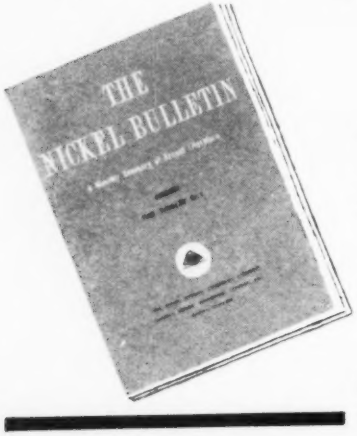

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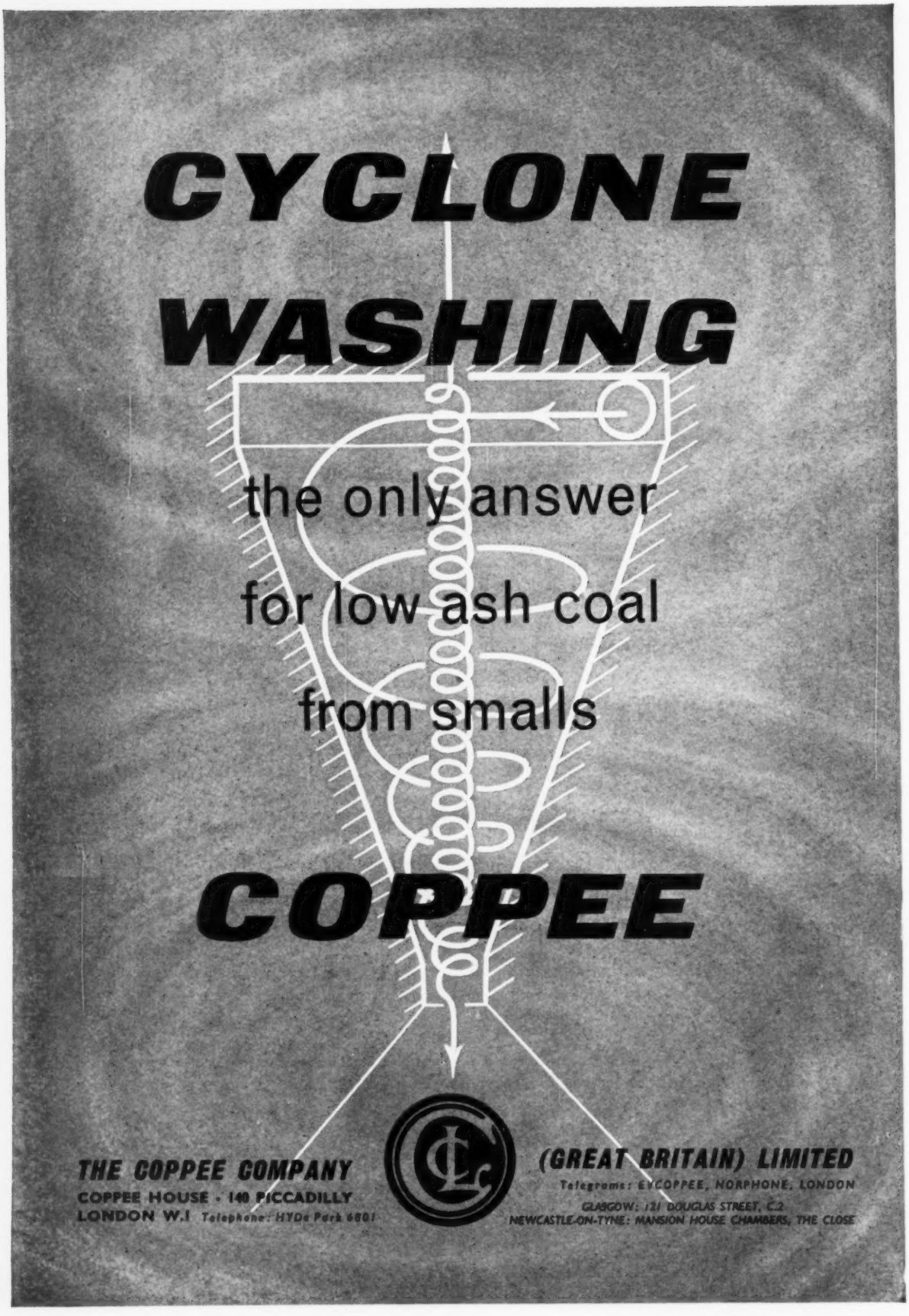
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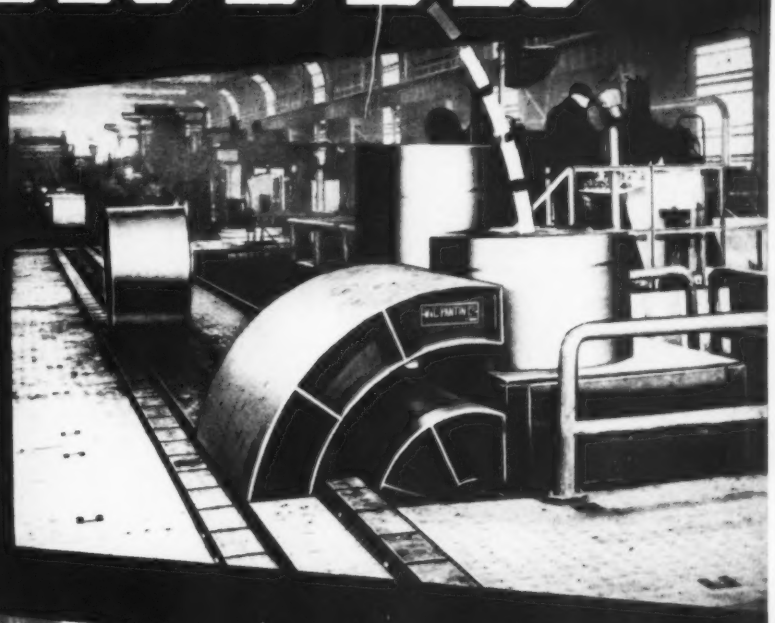

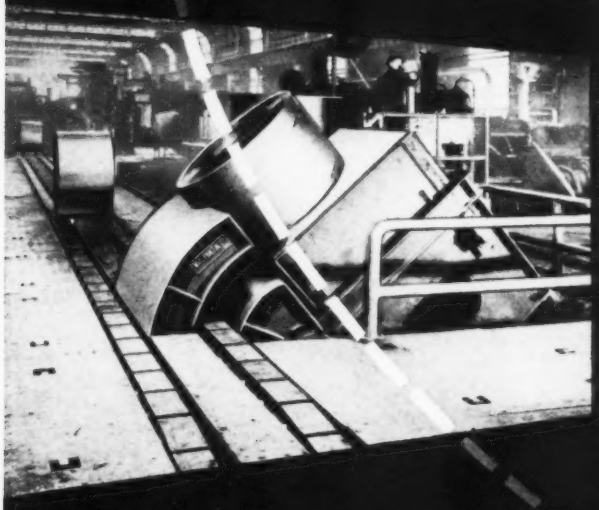

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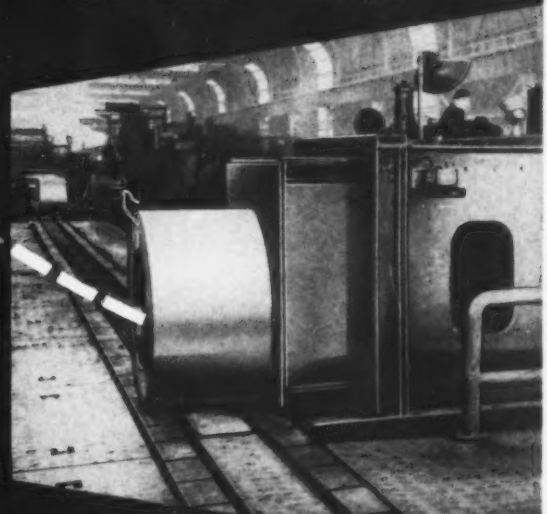

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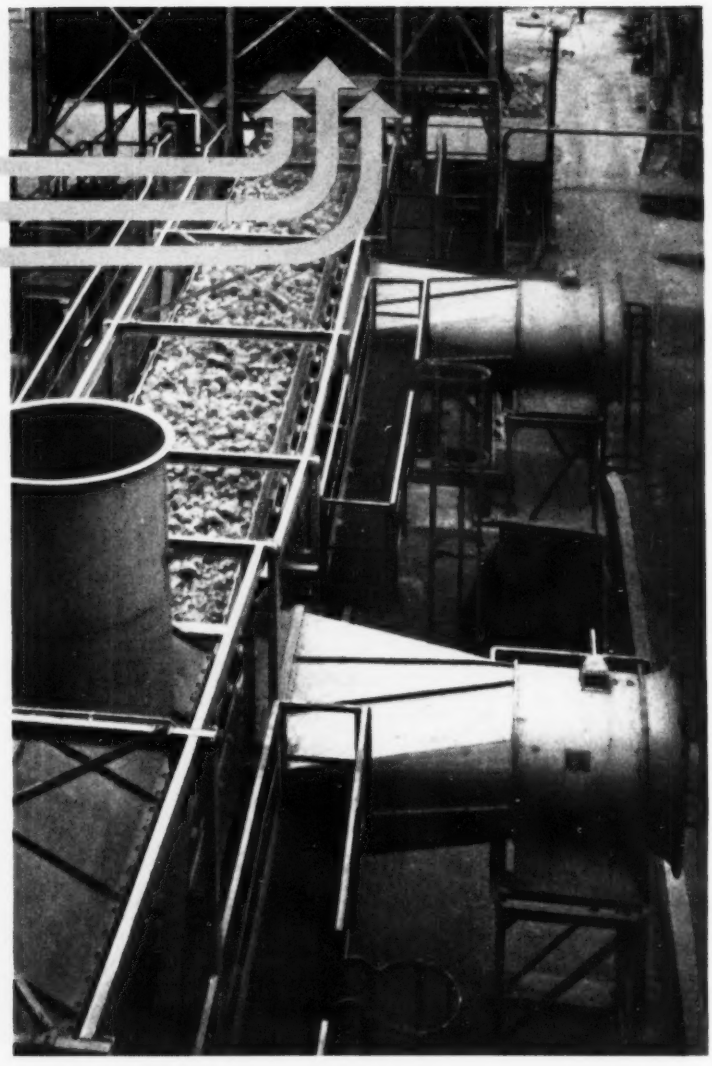

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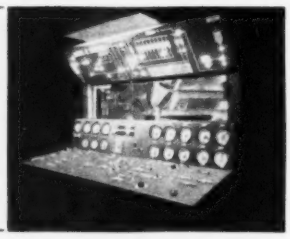

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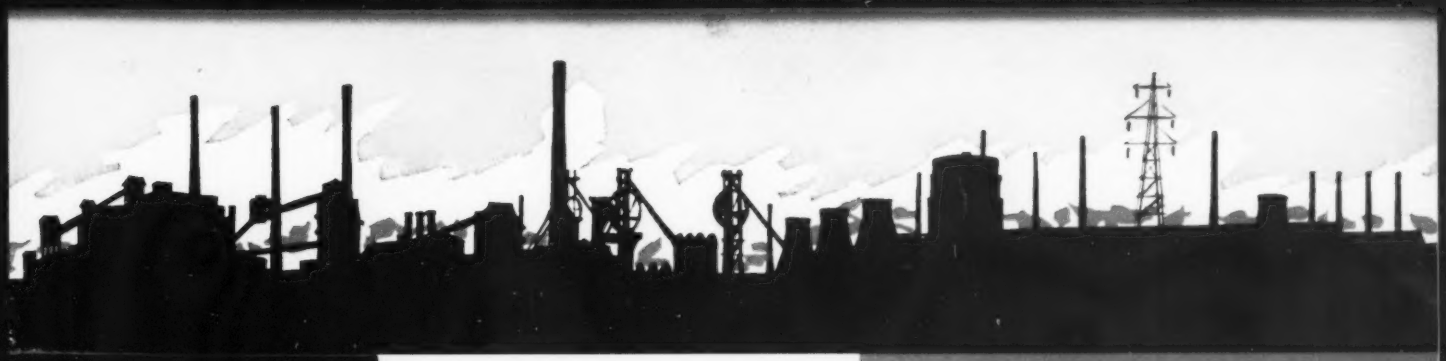

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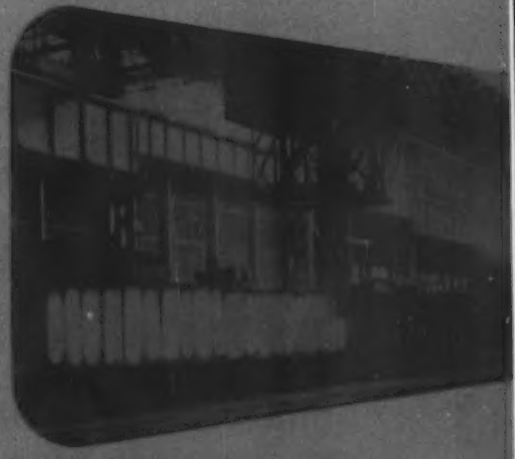

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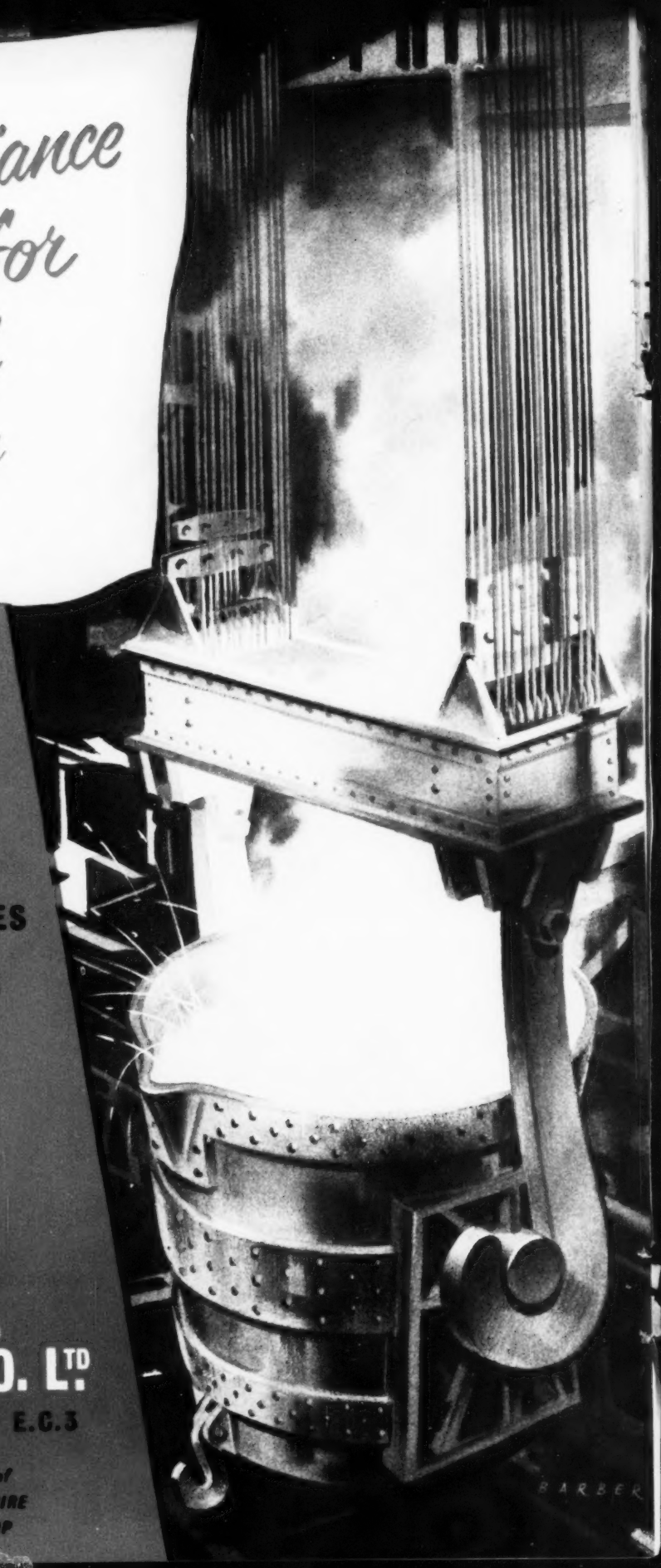

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Incorporating the Steelworks Divisions of
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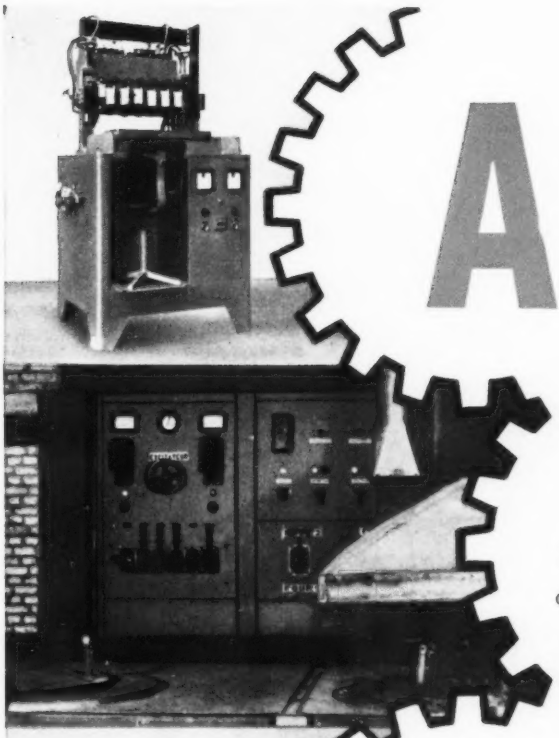

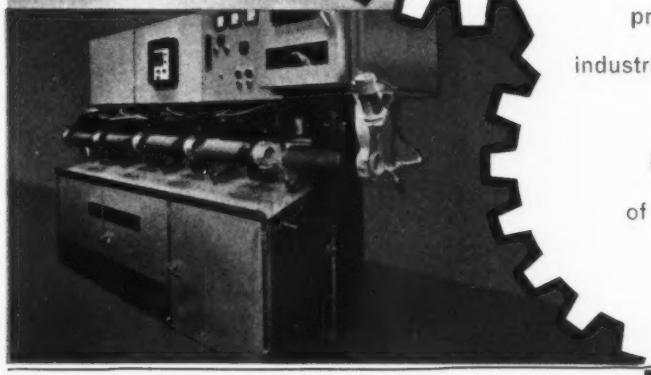

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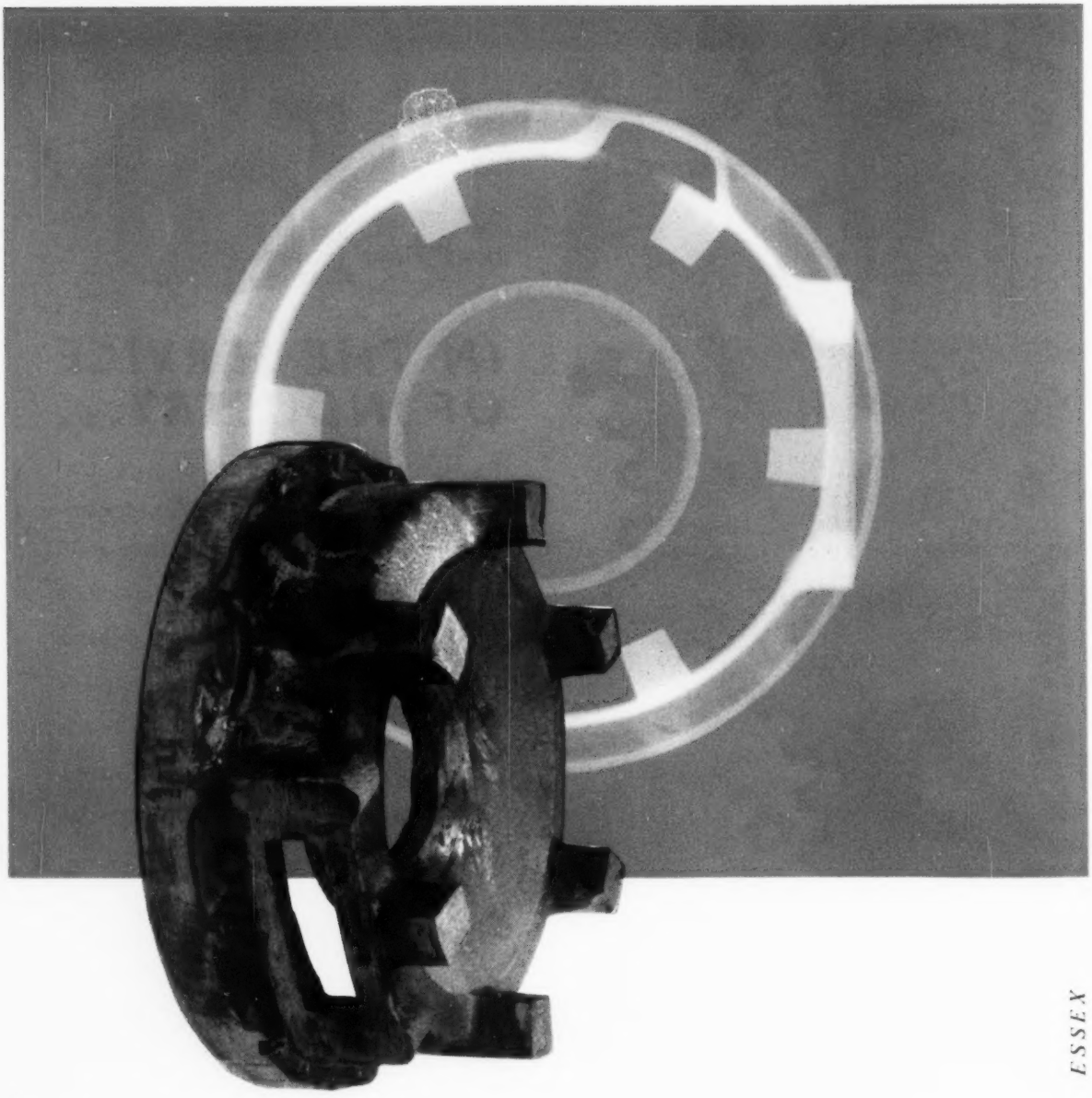

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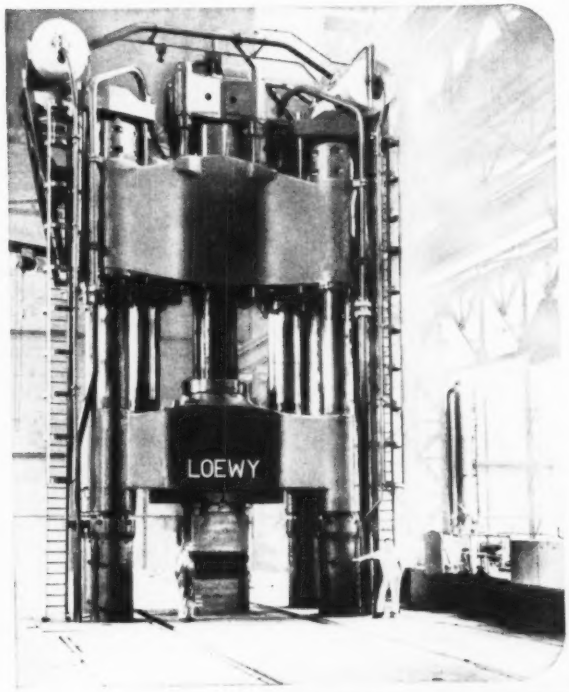

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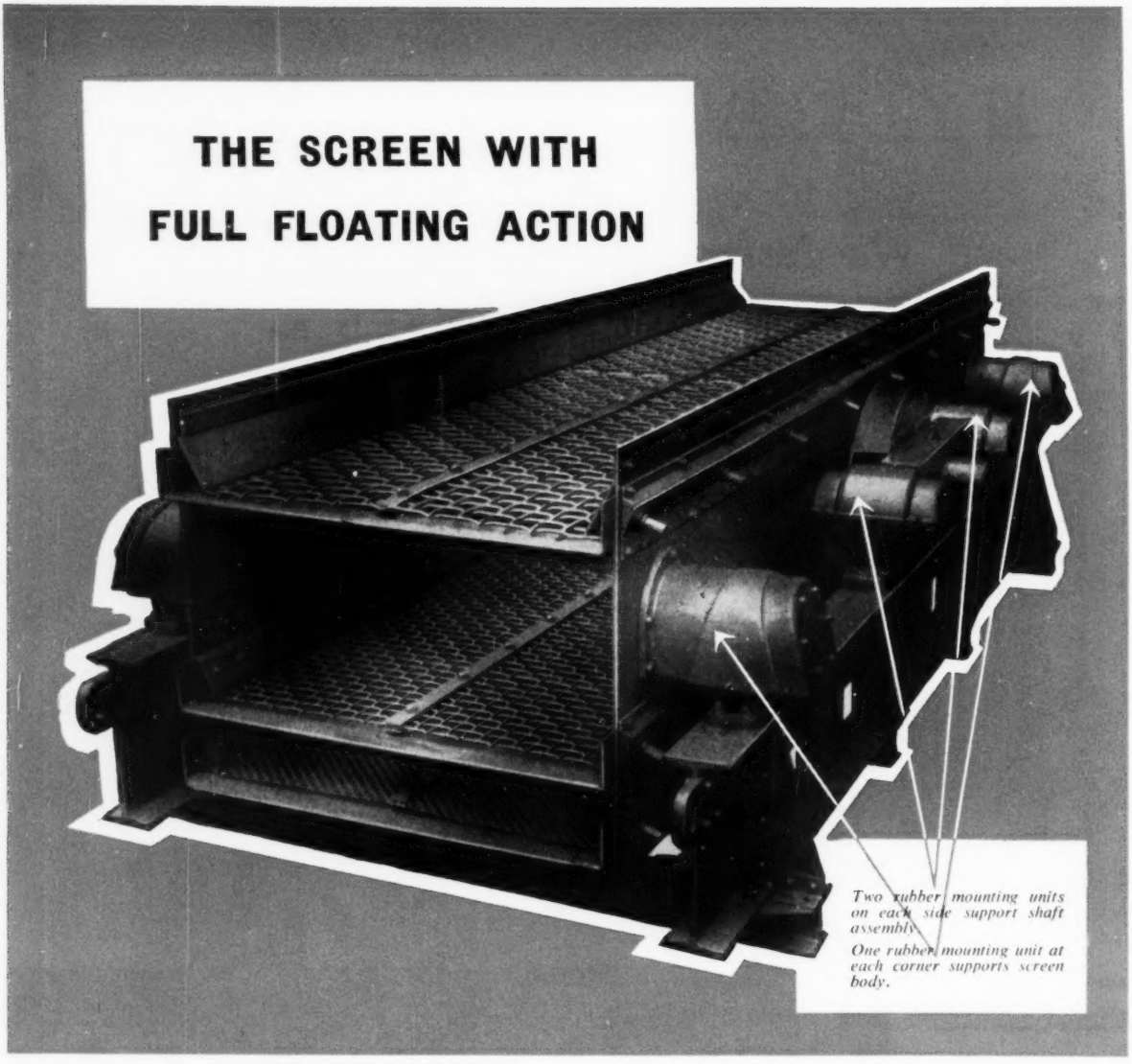
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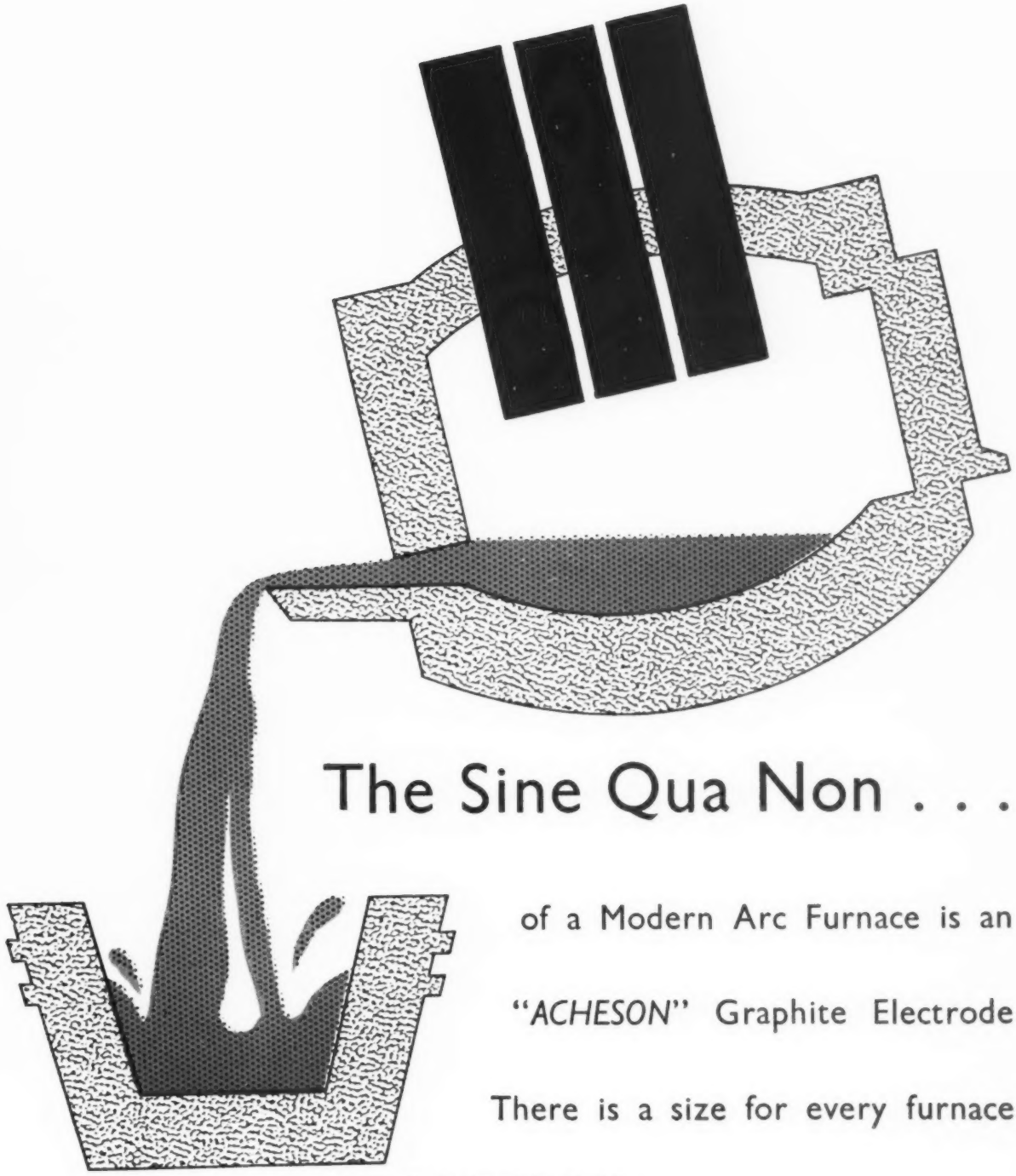

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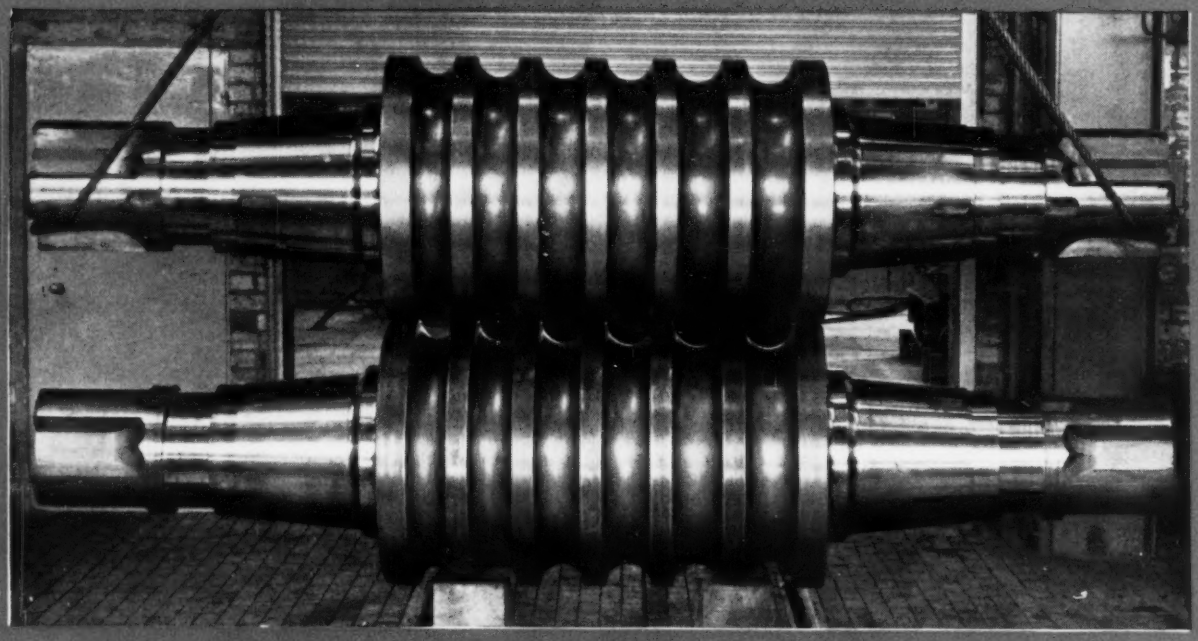
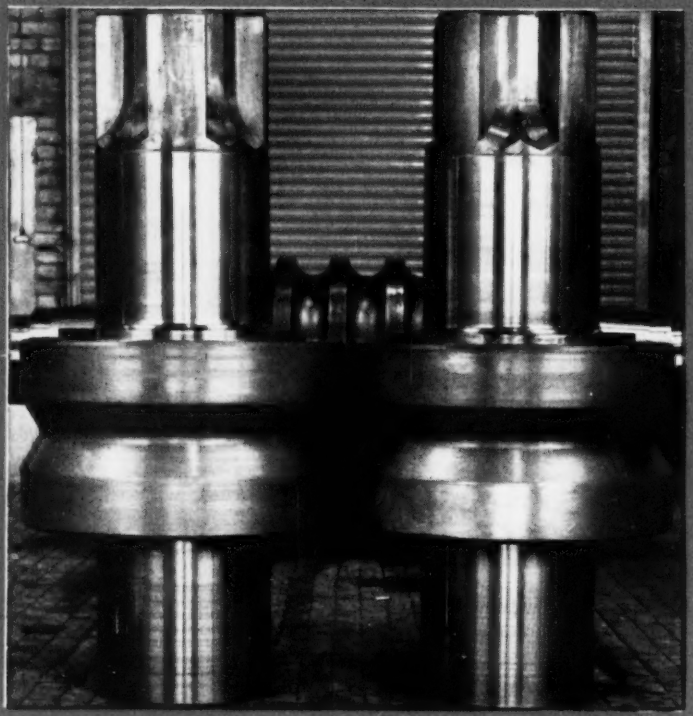


A pair of our Special "SSXH" Mooralloy Quality Rolls for Finishing Large Rounds 4¼" to 6" dia. for No. 6 Stand Roll size 32" dia. x 54" long barrel



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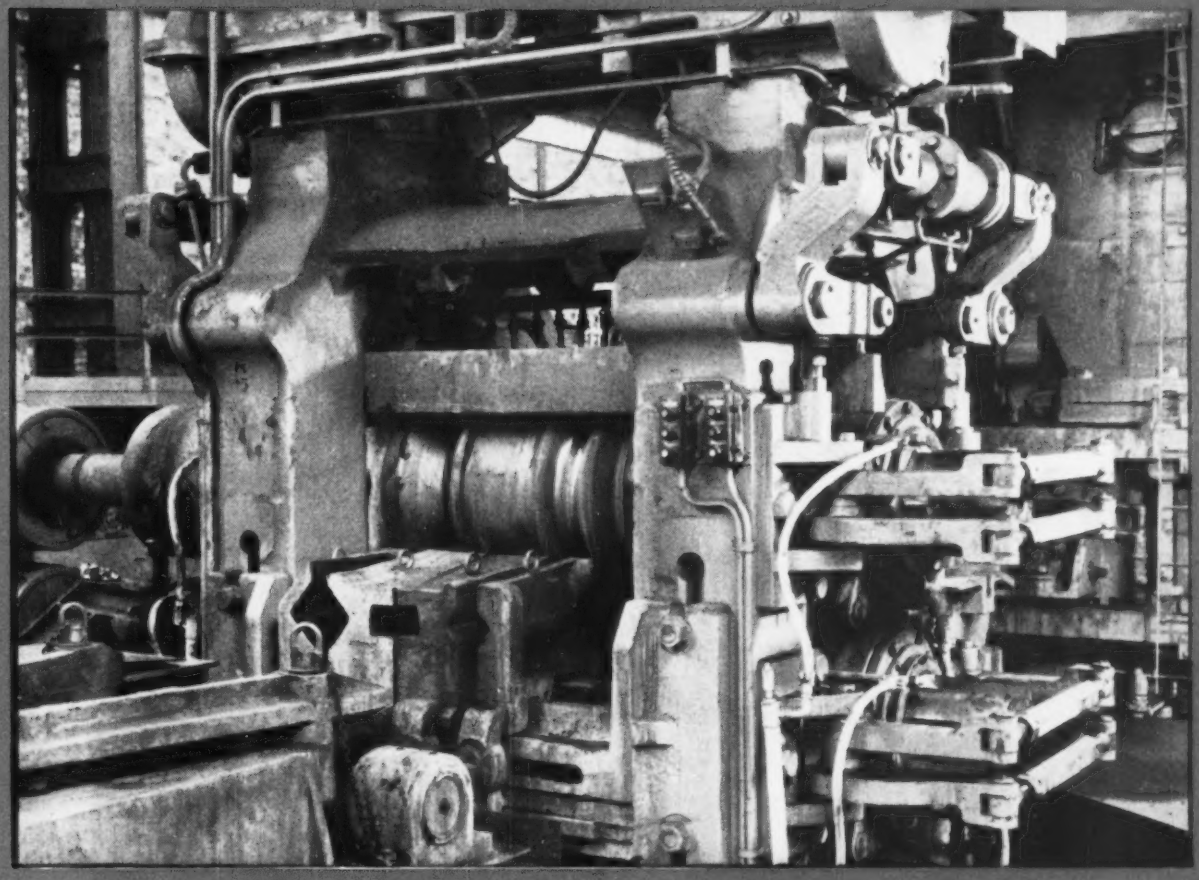

No. 6 Stand Finishing for 4", 4¼" and 5" Billets, also Roughing for 2" to 3½" Billets and Slabs at Consett Iron Co., Ltd showing our Special S.S.X. Mooralloy Quality Rolls. Roll size 32" dia. x 54" long barrel.

Photographed by the courtesy of The Consett Iron Co. Ltd.

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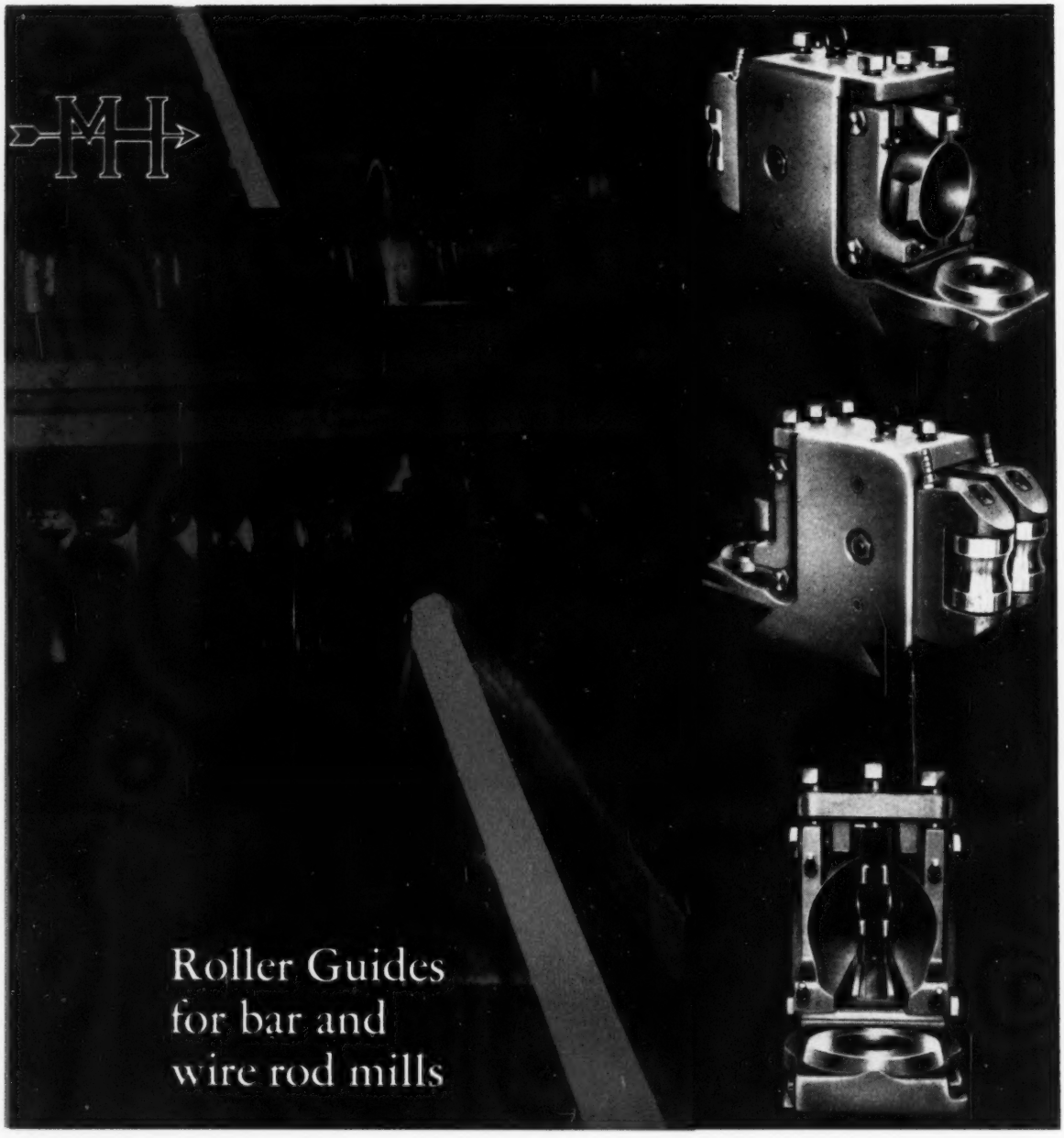

Morgårdshammar roller guides can be used for many sections such as leader and break-down ovals, squares, hexagons and octagons.

They can handle dimensions from about 3/16 in. (5 mm) round up to nearly 8 in. (200 mm).

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P.S.
In Scandinavia every bar and wire rod mill uses Morgårdshammar roller guides.

Swedish Quality

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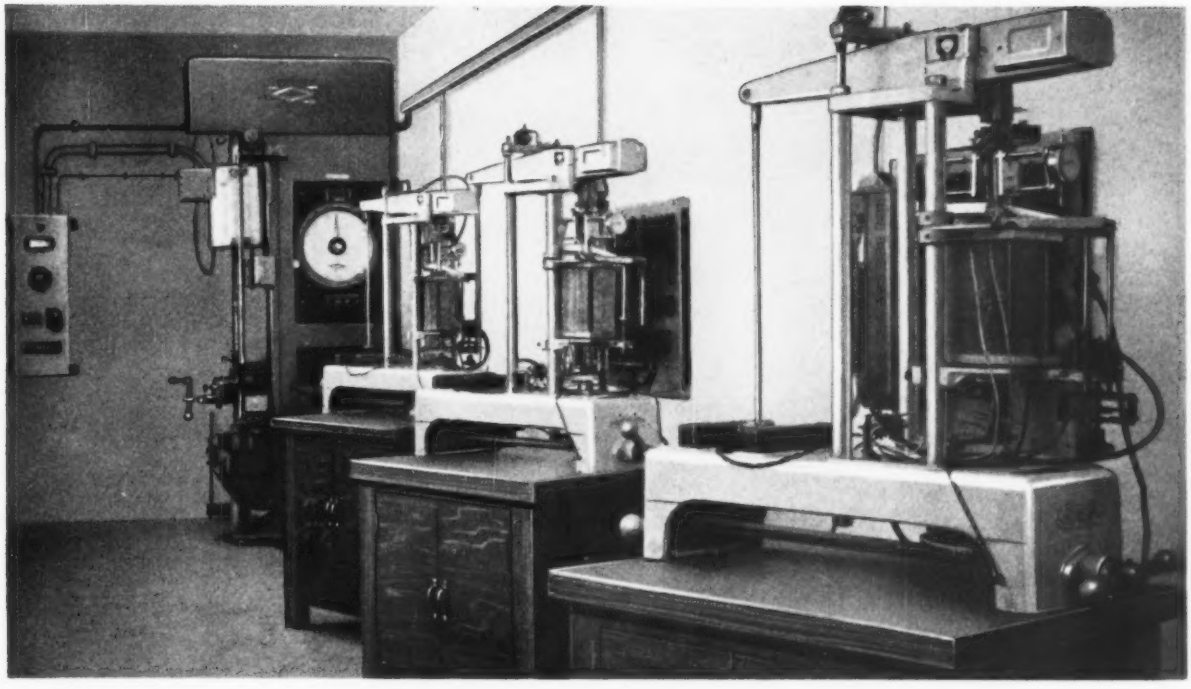

GUARANTEED PERFECTION OF ALLOYS' BEHAVIOUR AT SERVICE TEMPERATURE

The usual room-temperature tensile tests are not good enough for Thompson L'Hospied. They know exactly how each alloy behaves under load at whatever temperature it will ultimately be maintained in service. Test results from Stress-Creep and High Temperature Tensile machines are correlated to give absolutely accurate information which ensures perfection in both alloy and design. Thompson L'Hospied Heat resisting castings and Centrifugal castings do a fine job and stay on the job longer. Our advisory service — backed by long experience with the Furnace Industry — is freely at your disposal. Ask a representative to call.

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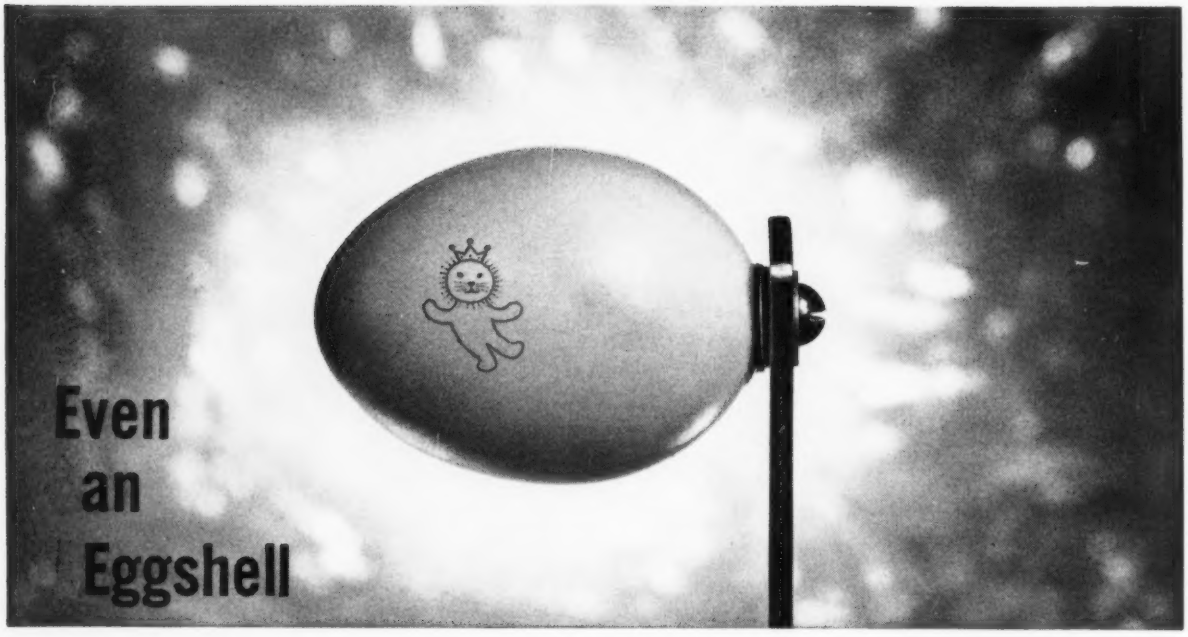

can be Screw-fixed with a RAWLPLUG FIXING DEVICE!

If you live to a hundred, you are unlikely to want to do much screw-fixing of eggshells! Yet this feat—possible only with a Rawlplug Fixing Device (a Rawlnut)—does serve to highlight the astonishing effectiveness of these Devices in making 'difficult' and even 'impossible' fixings simple and straightforward. Whatever the screw or bolt fixing job, you'll save time, money and temper by using the appropriate Rawlplug Fixing Device.

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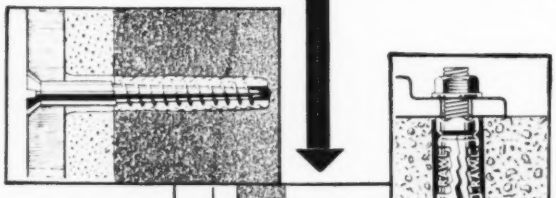

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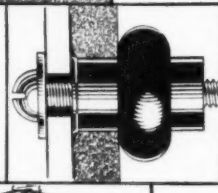
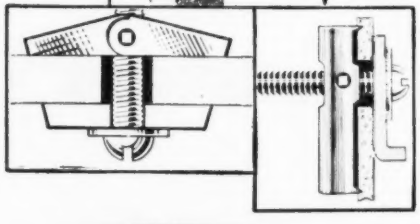
For light or heavy bolting jobs. A dry fixing of enormous strength—no cold chiselling, no waiting for cement to harden. In all bolt diameters up to 1".

RAWLNUTS
The amazing Rawlnut forms its own 'rivet head' behind the material when screwed up from the front. Shakeproof and waterproof, it has many valuable uses in both building and manufacture.



SPRING TOGGLES
For making firm fixings to such thin and structurally weak materials as plasterboard, ceilings, etc. The wings of the device spring apart behind the material and spread the load over a wide area.



GRAVITY TOGGLES
Passed through a hole in hollow material, the long member falls into a vertical position by gravity, and is then drawn against the back of the material by screwing from the front.

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RAWLPLUG WALL PLUGS

FIXING DEVICES *For Speed and Strength!*

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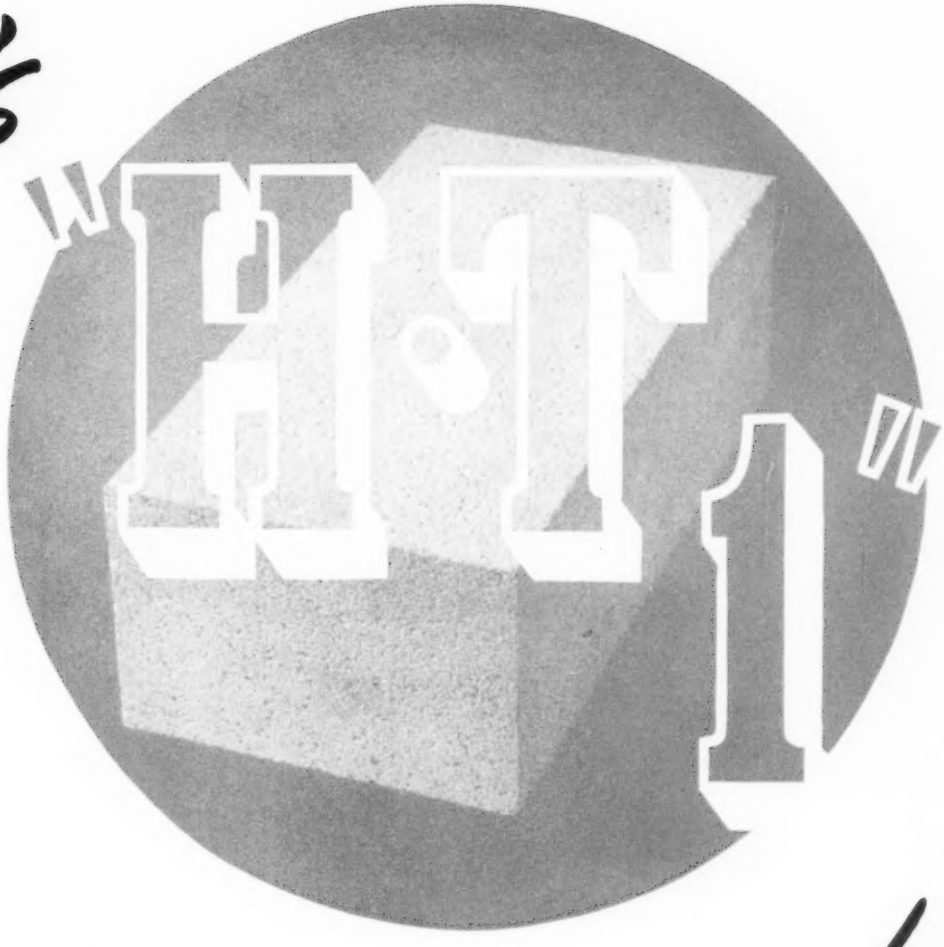

from experience!

From experience Gibbons "H.T 1" insulating refractory is the automatic choice of leading furnace manufacturers and users — its combination of low thermal conductivity with resistance to high temperatures has proved remarkably effective in minimising heat losses and raising furnace outputs. The Gibbons "H.T 1" is developed from more than 20 years' experience in the manufacture of insulating refractories and today an entirely new and original manufacturing technique enables us to offer material having unique physical properties at a price you can afford to pay.

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Refractory Insulating Concrete · Concrete Aggregates · Super-Plastic Jointing Cements · Surface Coating Cements

Gibbons (Dudley) Ltd., Dibdale Works, Dudley, Worcs. Telephone: 55141

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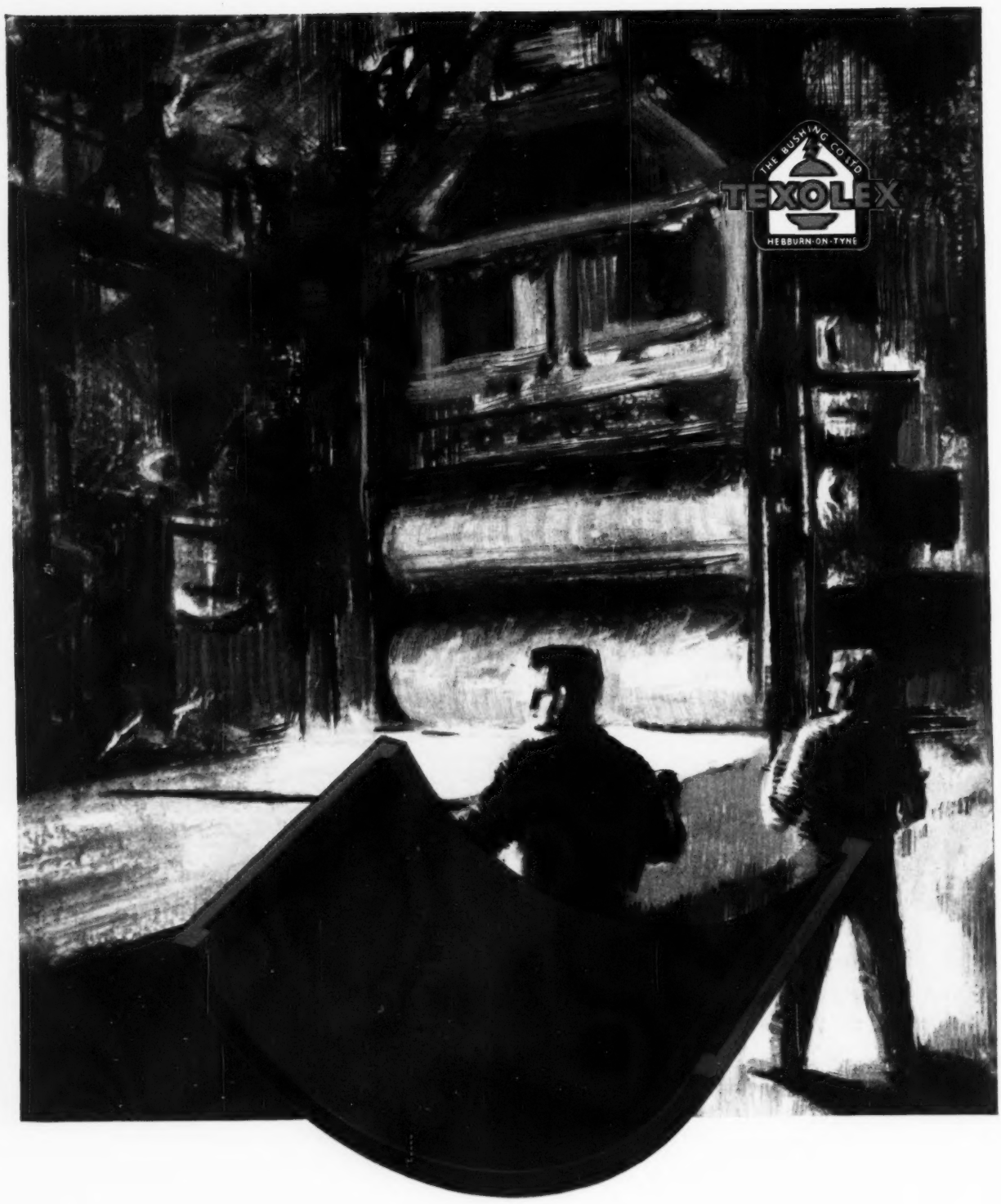

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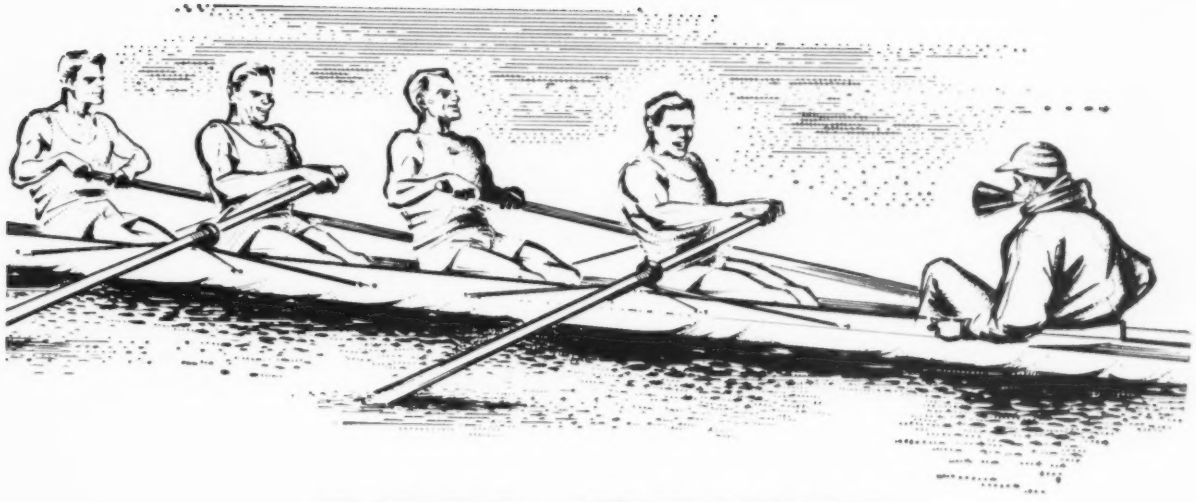

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We have yet to see the prowess of our designers as oarsmen but the essential characteristics of smoothness of action, economy of effort, flexibility, staying power and making light of weight are apparent in their products.

The Class 'E' circuit-breaker with patented lever operated sliding 'Isolector' contacts provides smooth, self-contained and rapid—

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BUSBAR SELECTION, on duplicate busbar units

No withdrawal of the truck is necessary, simply choose the function required, insert the lever, and operate from the front of the unit. The exact state of the circuit-breaker is always visible on a mimic diagram whether the door is open or closed. Class 'E' air-break switchgear is designed for 3·3 kV and 6·6 kV service, with current ratings up to 3,000 amps.

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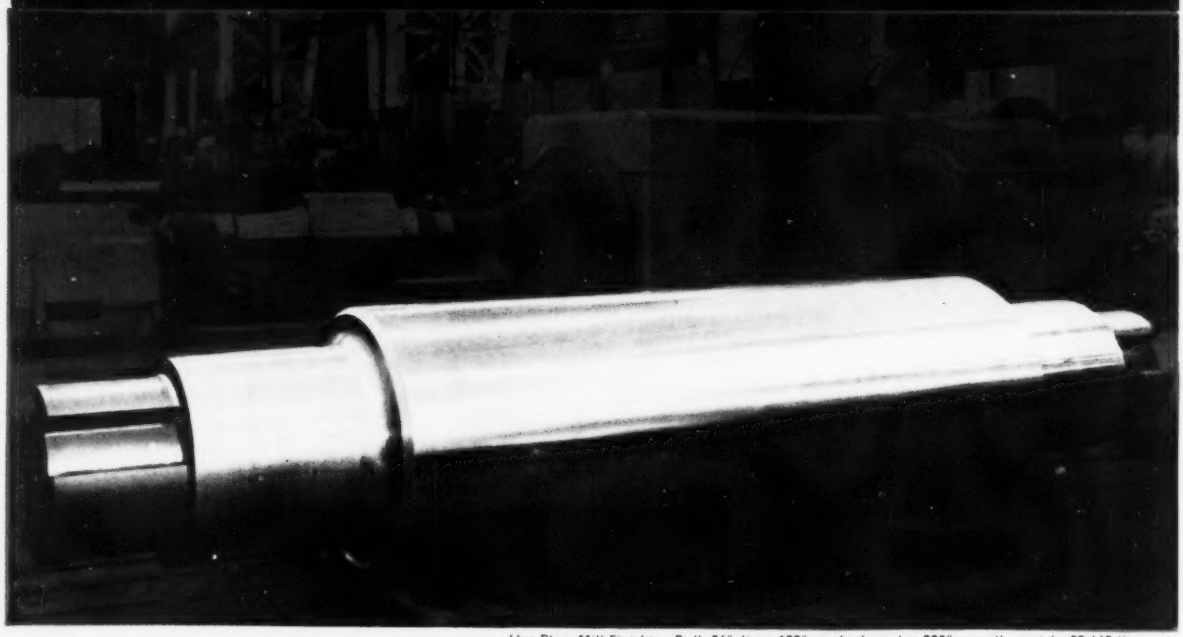
The Brightside range of rolls for hot and cold rolling is keeping pace with the exacting requirements of the steel and non-ferrous industries at home and abroad.



Hot Plate Mill Finishing Roll, 36" dia x 108" on the barrel x 203" overall—weight 38,640 lbs. each

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Mobil D.T.E. Oils for protection and performance

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LESS WEAR

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ASK THE MAN FROM MOBIL ABOUT BALANCED OILS

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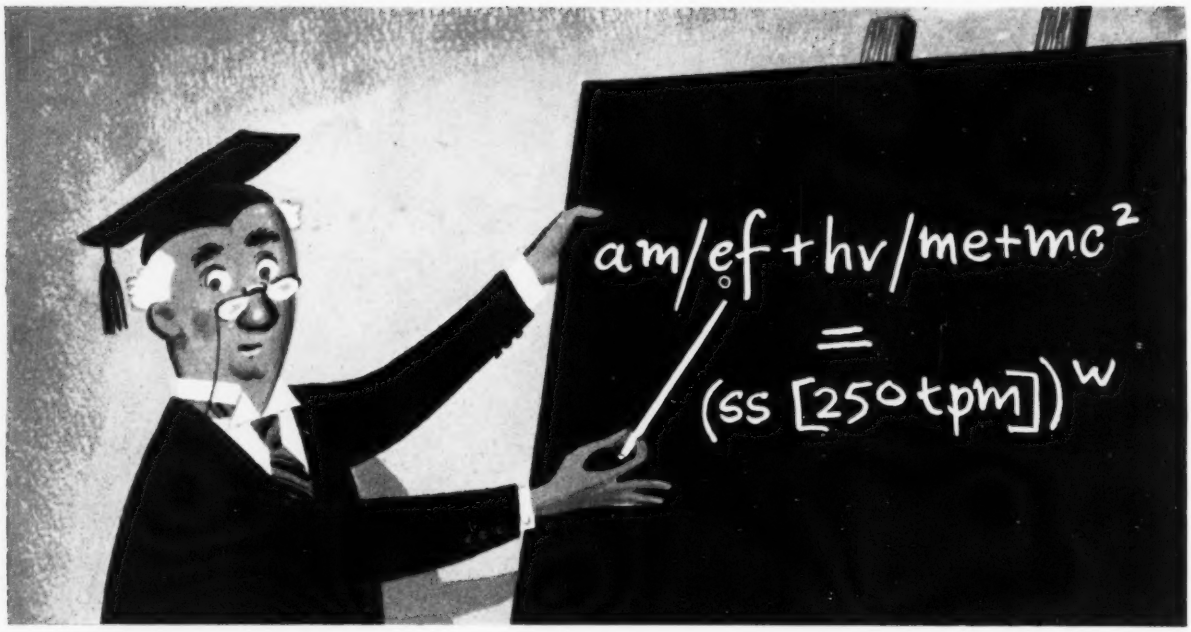

"Who can simplify this equation?"

"Oh sir, please sir, me sir. You can say 'Willans=Special Steels'."

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"Well sir, air melting electric furnaces plus high vacuum melting equipment plus lots and lots of metallurgical control equals special steels at 250 tons per month, all to the power of Willans. Isn't that right sir?"

"Absolutely right, boy. Go to the top of the class."

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Specialists in special steels. All types. 250 tons per month. Melting stock, ingots, billets, bars—standards or to your specification. Delivery?—quick Quality?—excellent. A.I.D., A.R.B., D.I. Arm? of course.

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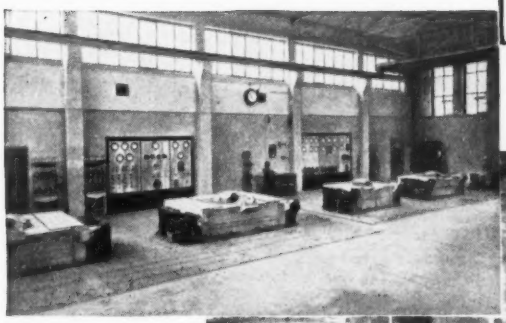
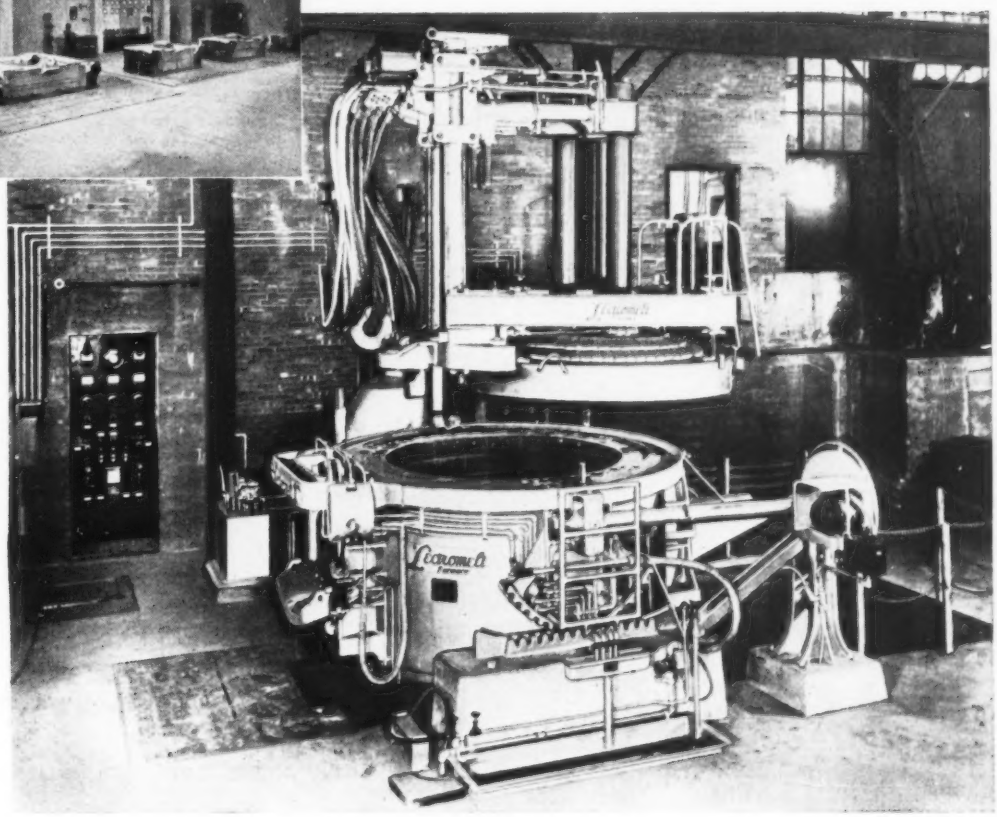
DEMAG

Lectromelt



Demag high-frequency induction furnace installation at a steel making plant, incorporating two 1 ton capacity furnaces, two 660 lb. capacity furnaces, and one 110 lb. capacity furnace.



4 3 ton capacity Lectromelt arc furnace of 9' 0" diameter shown with roof swung ready for charging.

High Speed and High Output are the key features in the medium and smaller range of furnaces offered by G.W.B. Furnaces Ltd. Many years are behind both the Coreless and Arc Furnaces of Demag and Lectromelt designs.

Daily, electric furnaces are finding wider and wider applications, and the coreless induction (crucible) type is no exception as it is an ideal medium for melting steel and iron, and all other metals. It is particularly advantageous in steel works where a charge of scrap of known analysis is melted and is an installation that pays for itself in a very short time. The proven economies of operation of electric arc furnaces offered by G.W.B. have earned an enviable reputation, and a few of their outstanding features are:—

Separately mounted roof lift and swing mechanism for top charging; Four point roof suspension of the roof ring; Electrode holders of the power operated, spring-held, air release type; High speed movement of the electrodes; Offset rocker centres to return furnace from extreme tilt in event of power failure.

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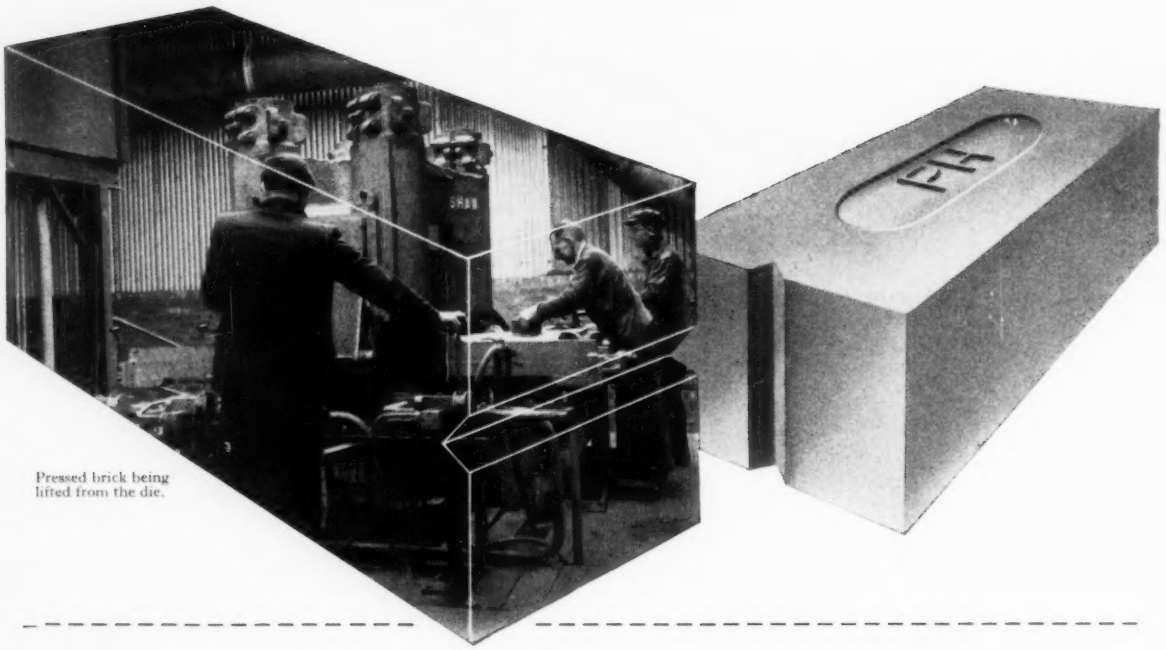
GWB 243



Pressed brick being lifted from the die.

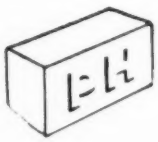
PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

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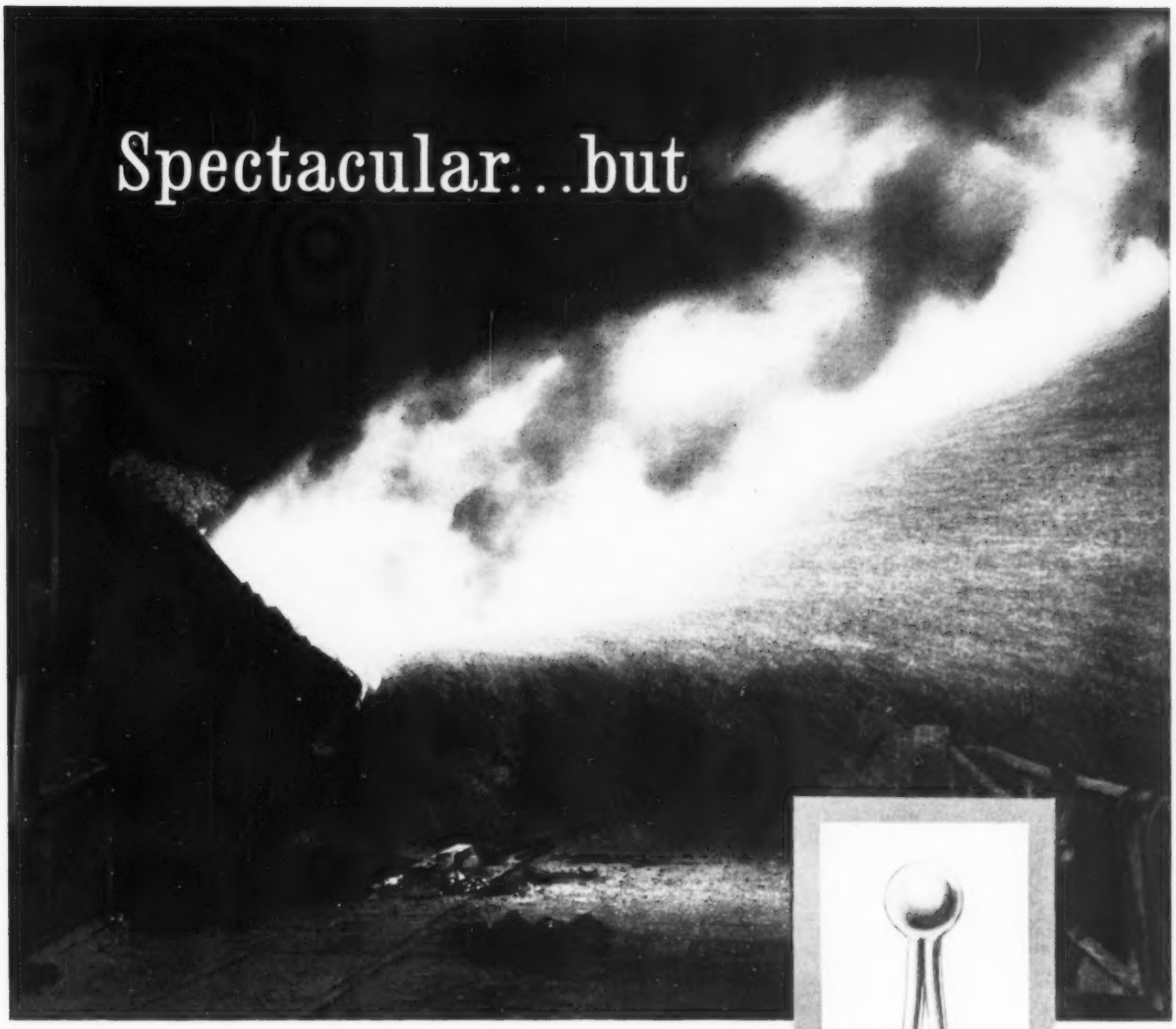
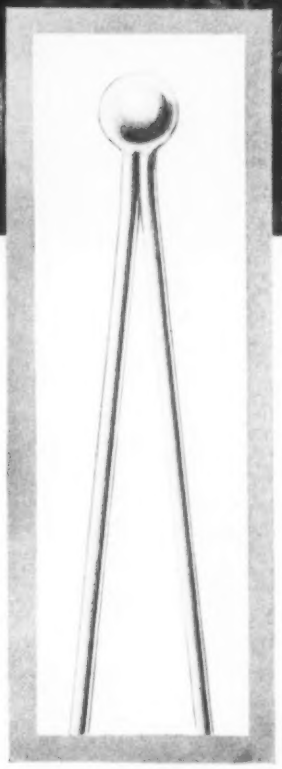
Spectacular...but





. . . but dependent so much upon the unspectacular the platinum:rhodium-platinum thermocouple, which plays a vital role in all high-temperature processes where accurate measurement is essential to exact control.

Simple, robust, consistent, the thermocouple is to both industry and research a means without equal of precise high-temperature determination.

Information regarding the properties of the platinum metals and their industrial application is freely available.

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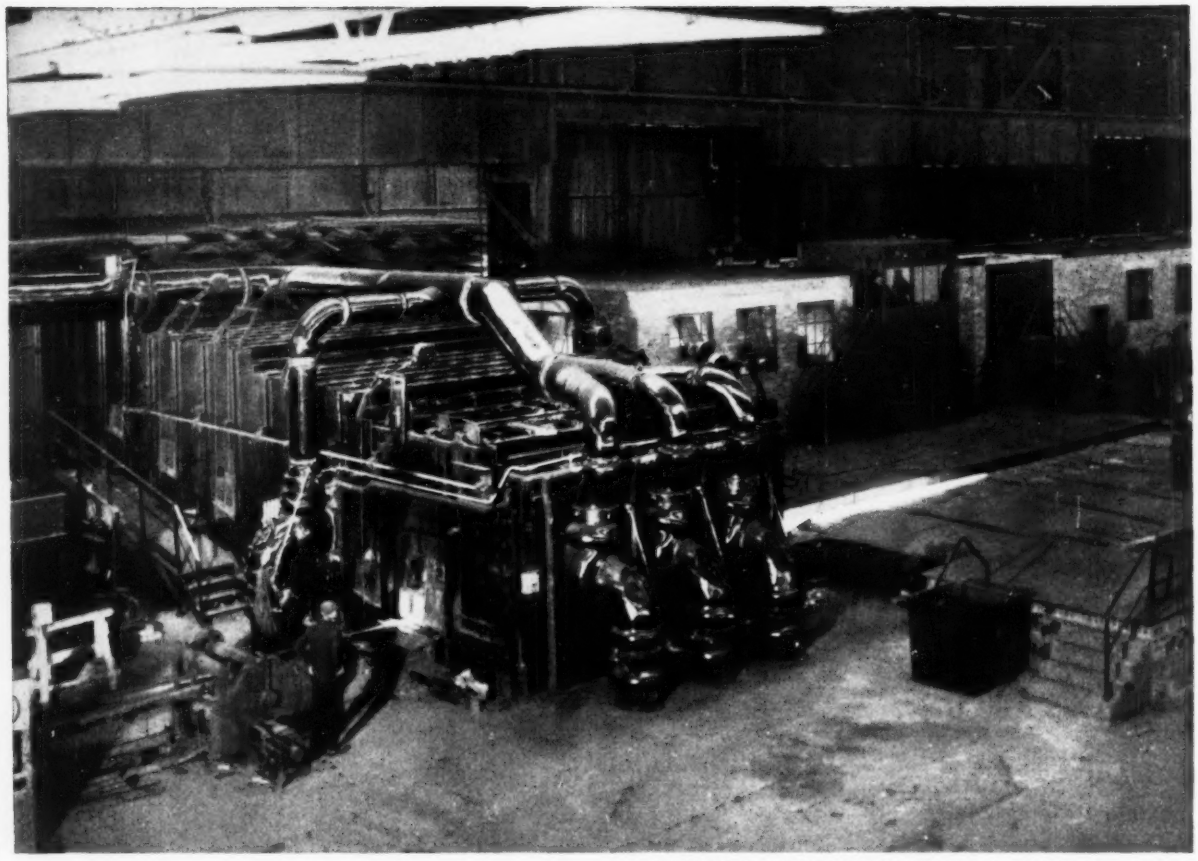
Vittoria Street, Birmingham, 1. Telephone: Central 8004. *75-79, Eyre Street, Sheffield, 1. Telephone: 29212.*



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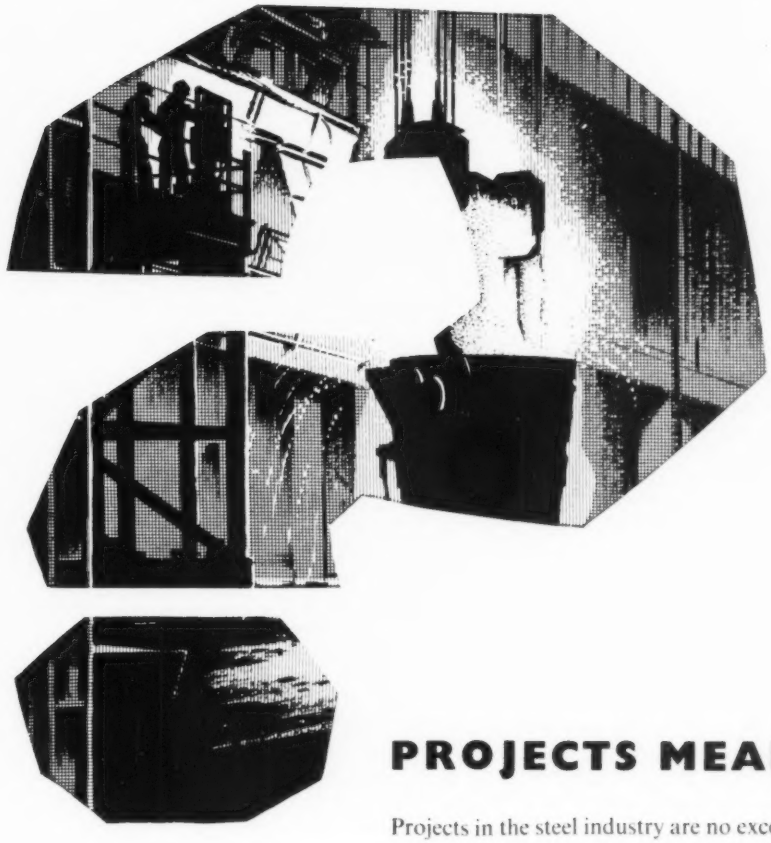

PROJECTS MEAN PROBLEMS

Projects in the steel industry are no exception. And among the problems posed by the new projects which are exciting the steel world today, gas cleaning and dust collection loom large.

Tonnage-oxygen practice on steel furnaces – the L.D. process on converters – bigger and better sinter plants – these new developments demand higher standards of performance from gas-cleaning and dust-collecting equipment.

Which of the various types of equipment available will provide the best answer to these problems and to others as they arise? Which will give the most efficient, most economical long-term service?

If *you* have to find the answer to these questions, remember that whatever conclusions theory may point to, the practical yardstick is that Simon-Carves Ltd. have first-hand operational experience, with the first open-hearth furnace precipitators in this country now in operation, and a repeat order in hand. They have also received the first order for an L.D. converter precipitator in this country, and are installing sinter gas precipitators in two European steelworks.

Future problems will best be tackled by the firm with field experience gained from full-scale plants in actual service – by the firm which has established a clear lead in electro-precipitation for modern steelmaking processes in this country. For further information write to CPP DIVISION (g.s.g.) AT ADDRESS BELOW.

HIGH EFFICIENCY ELECTRO-PRECIPITATION BY

Simon-Carves Ltd

SIMON ENGINEERING GROUP

STOCKPORT, ENGLAND

and at CALCUTTA · JOHANNESBURG · SYDNEY · TORONTO

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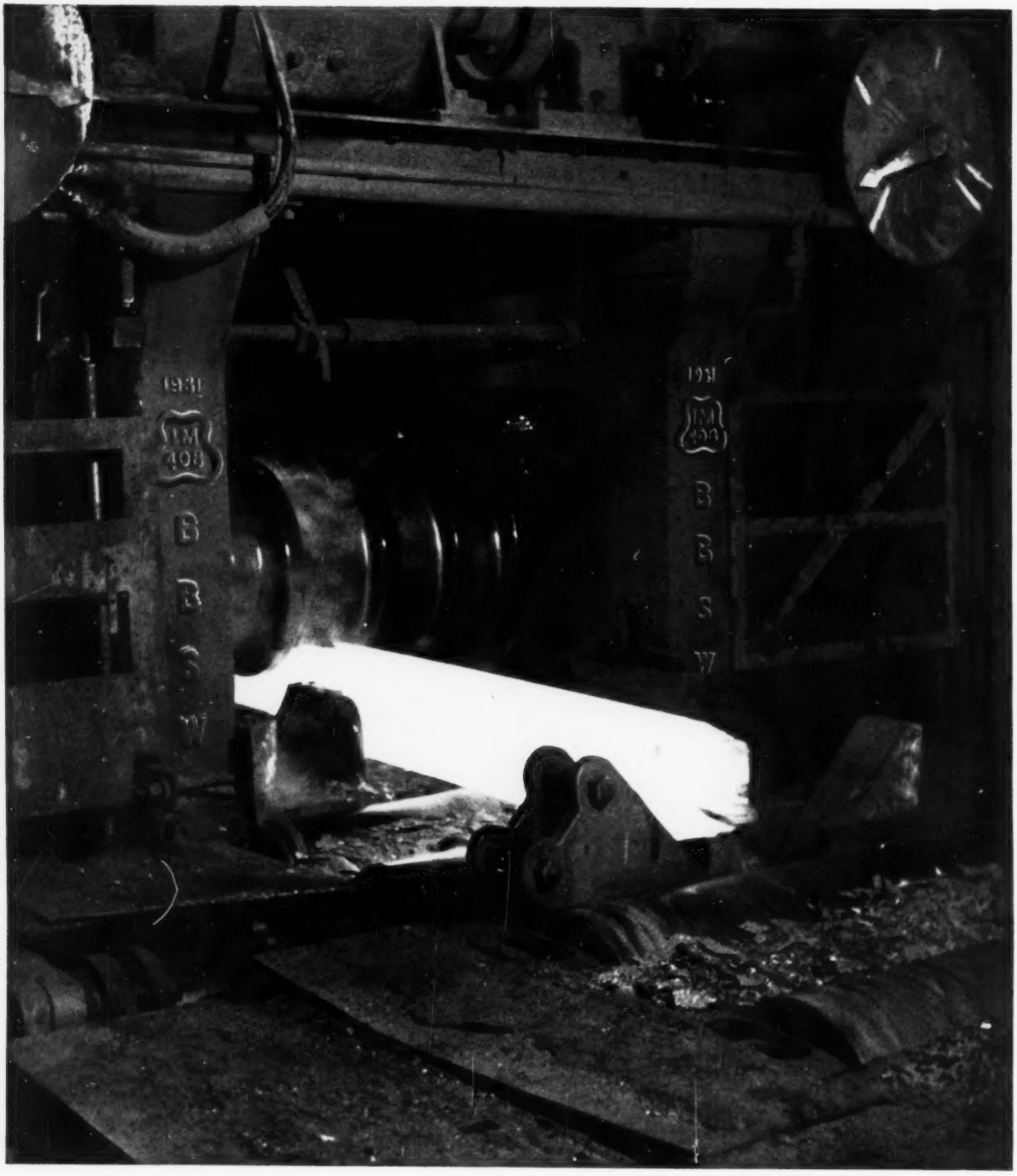
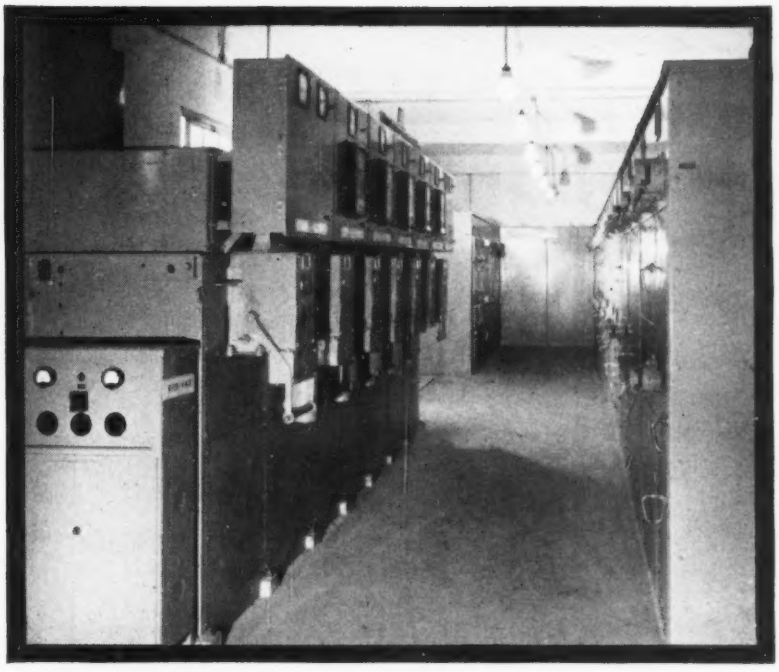


BROWN BAYLEY STEELS LIMITED SHEFFIELD

BROWN BAYLEYS



Equipment illustrated is typical of the multi-panel contactor boards, switchboards and supervisory control stations supplied to the orders of Messrs. Huntington, Heberlein & Co. Ltd., Moxey Ltd., and the Dalyte Electrical Co. Ltd. *Photographs by courtesy of The Stanton Ironworks Co. Ltd.*

Allen West Control Gear at STANTON

For that outstanding engineering achievement, the new Ore Preparation Plant of the Stanton Ironworks Company, Allen West & Co. Ltd. have been privileged to supply no fewer than seventeen composite switchboards. These embody the controls for over two hundred drives, ranging from ¼ to 200 H.P., in the Crushing, Screening and Sintering Sections of the 40-acre installation.

Robustness and reliability, allied to technical efficiency, are established features of Allen West products, which have been specially designed to withstand the most arduous conditions.

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FIFTY YEARS OF
CONTROL GEAR DEVELOPMENT

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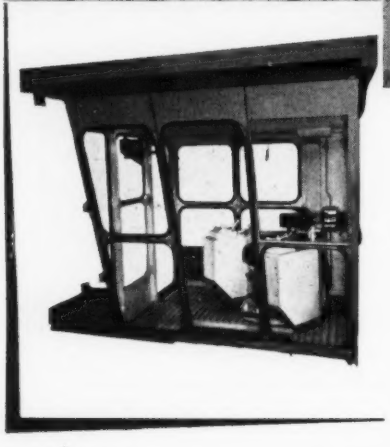
ELECTRIC OVERHEAD TRAVELLING CRANES



★ *a view of the cab showing the seat control unit.*

The Adamson 50/10 ton crane is the third of a series of new design supplied to Richard Thomas & Baldwins Limited, Ebbw Vale Section. Features of the crane include monolithic construction of the crab and the elimination of castings by mild steel fabrication of the hoist barrel and bottom block. The cab is of particular interest as it incorporates the most modern type of seat unit ensuring maximum vision and ease of control. Joseph Adamson electric overhead travelling cranes can be supplied to all specifications including cranes suited to the most exacting 24 hours-a-day process work.

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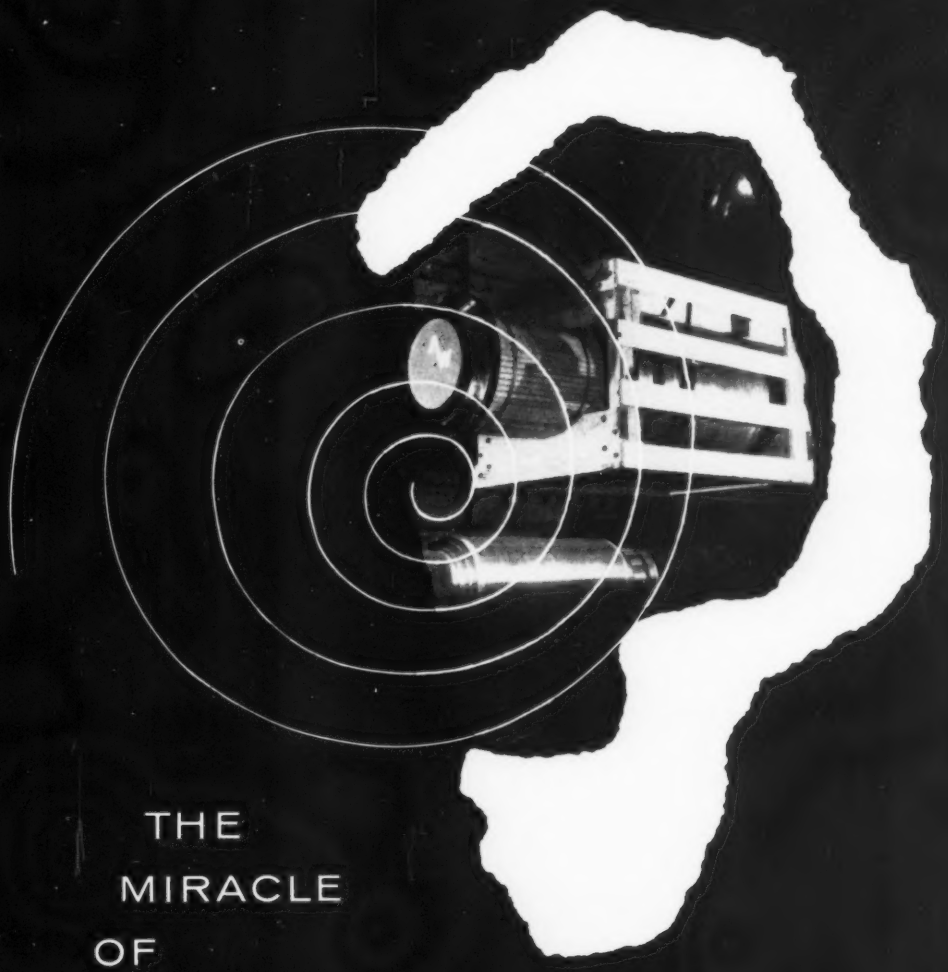

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These very high frequency waves are sent through each Roll and the time of their reflected return is measured electronically. Should the waves encounter even the smallest crack or cavity they will be reflected prematurely and pin-point any flaw with accuracy.

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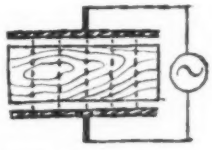
VISCO-BETH
Dust Collectors

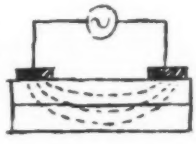
FWS

Dielectric Heating - 1

When an electrically non-conducting material is placed between two metal plates, called electrodes, connected to an A.C. supply, the alternating electrostatic field between the electrodes considerably speeds up the molecular movements in the material (termed a 'dielectric') as a result of which the temperature of the material under treatment rises. A similar effect is produced where the two electrodes are positioned on the same side of the dielectric; in this case the electrostatic field between them is generally known as a 'stray' or 'fringe' field.



For industrial application, the applied voltage of the order of 15,000 volts supplied by an electronic generator alternates at frequencies of some millions of cycles per second.



The amount of heat generated in the dielectric is determined by the frequency, the square of the applied voltage, the dimensions of the object and a physical property of the material termed "loss factor" and is represented by the equation:—

$$\text{Power} = 1.41\ E^2\ f.\ F\ \frac{A}{t} \times 10^{-15} \text{ kilowatts.}$$

Where E = applied voltage, f = frequency, F = loss factor.

A = area of the dielectric in square inches.

t = thickness of the dielectric in inches.

F, the loss factor, is itself equal to the expression K Cos Ø in which:

K = the dielectric constant, a measure of the property of the material to retain energy arising from disturbance of its molecular structure.

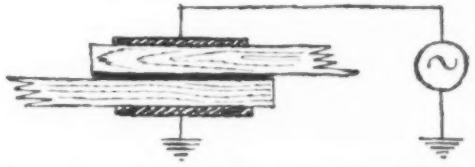
Cos Ø = the dielectric power factor of the load, that is the ratio of the power (in watts) to the product (in volt-amperes) of the voltage and current. This is a characteristic property of the material.

Therefore, "loss factor" is a property of the material and a measure of the ease with which it can be heated by this method. Like other physical properties, it varies considerably for different substances. The equation shows that the heat generated in a dielectric is proportional to its loss factor, but the rate of rise of temperature will also depend upon its specific heat and density. The following table gives approximate values of the dielectric constant, power factor and loss factor of a few typical dielectric materials for frequencies around a million cycles a second.

MATERIAL	DIELECTRIC CONSTANT	POWER FACTOR	LOSS FACTOR
Natural Rubber	2.9	0.02	0.058
Oak, dry	3.3	0.04	0.132
P.V.C.	5.3	0.06	0.318
Urea formaldehyde	7.0	0.03	0.21
'Bakelite' resin	6.0	0.03	0.18
Nylon	3.7	0.05	0.185
Water, pure	80.0	0.03	2.40
Water, tap	80.0	0.5/5.0	40/400

The high loss factor of water means that materials which are difficult to heat when completely dry will often heat efficiently when moisture is present. The voltage must be increased towards the end of the process in some cases to remove the final moisture traces, the reduction in loss factor as the material dries out providing a safeguard against overheating.

Dielectric heating of a homogeneous material is a straightforward application, heat being generated uniformly throughout. If the workpiece is made up of a number of materials, each material will heat up uniformly but each at a rate depending upon its loss factor, thermal properties and density. The degree of temperature uniformity throughout the workpiece will then depend upon the extent to which thermal conductivity can equalise different rates of heating.



Such different rates of heating can be turned to good account in certain applications. For example, in wood glue setting, the glue lines heat up much more rapidly than the wood pieces being joined and the glue sets before the wood heats up substantially, wood having a lower loss factor than glue. Dielectric heating does not depend upon any external heat source to transfer heat by conduction, convection or radiation to the surface of the charge and from thence to the interior by conduction.

Instead, heat is generated within every particle of a body placed in the dielectric field and, depending upon the uniformity of such a body, an even and extremely fast temperature rise can be achieved.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

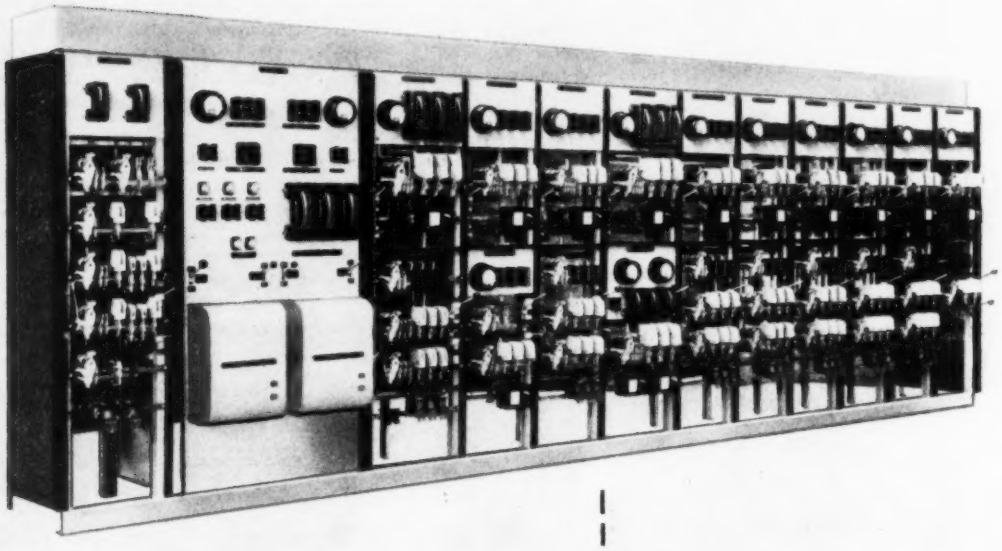
Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available—"Induction and Dielectric Heating" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

6776

CUT HERE

Steel Works Contactor Gear



One of the many control boards together with control desks supplied to The Steel Company of Wales Limited for the Coiling, Cut up and Finishing Lines at their Abbey Works.

Contactor Switchgear Limited manufacture automatic electric control gear (up to 6,600v. A.C. and 650v. D.C.) for Power Station Auxiliaries, Steel Works, Water Works, Rolling Mills, Sewage Works, Chemical Plants, Gas Works and Cement Works, including Cranes, Electric Furnaces, Machine Tools, Fans and Pumps.

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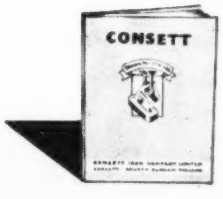

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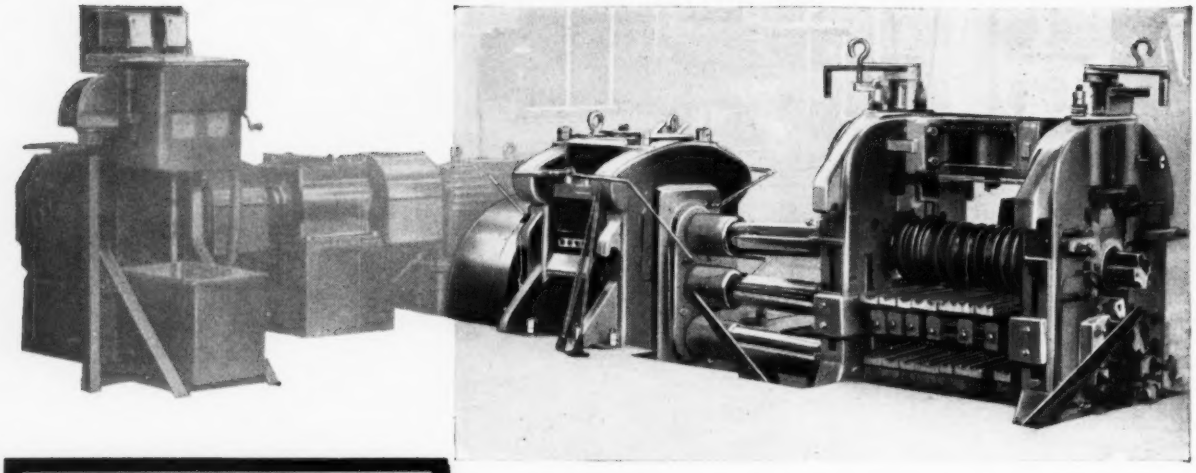
Our Technical and Research Department will also welcome enquiries from any whose problem is . . . . STEEL

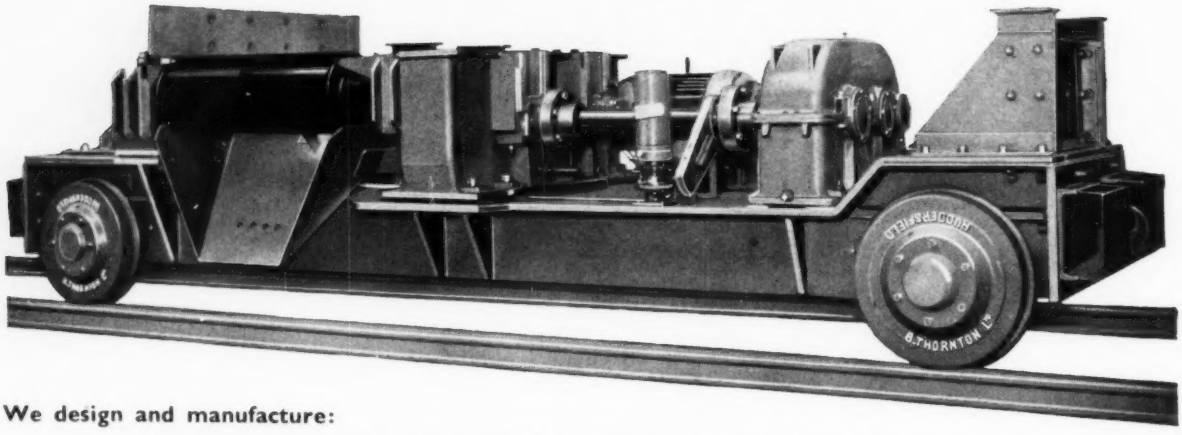


Thornton

Engineers and Contractors

12" Mill as supplied to Swinden Laboratories, Rotherham, and published by courtesy of The United Steel Companies Ltd.

Ingot Transfer Car for conveying 4/5 ton Ingots.



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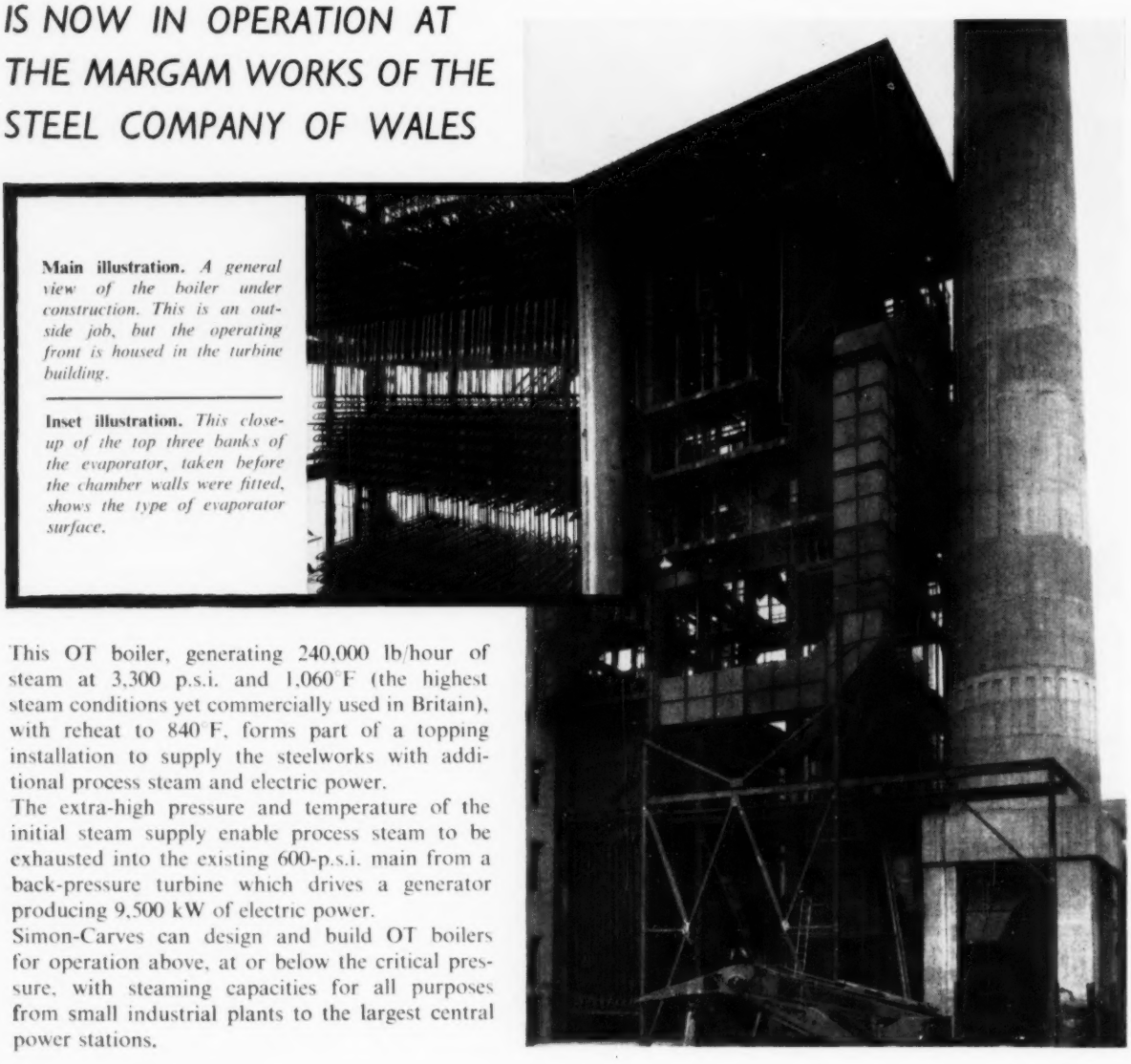
ONCE - THROUGH FORCED - CIRCULATION BOILER

IS NOW IN OPERATION AT THE MARGAM WORKS OF THE STEEL COMPANY OF WALES



Main illustration. *A general view of the boiler under construction. This is an outside job, but the operating front is housed in the turbine building.*

Inset illustration. *This close-up of the top three banks of the evaporator, taken before the chamber walls were fitted, shows the type of evaporator surface.*

This OT boiler, generating 240,000 lb/hour of steam at 3,300 p.s.i. and 1,060°F (the highest steam conditions yet commercially used in Britain), with reheat to 840°F, forms part of a topping installation to supply the steelworks with additional process steam and electric power.

The extra-high pressure and temperature of the initial steam supply enable process steam to be exhausted into the existing 600-p.s.i. main from a back-pressure turbine which drives a generator producing 9,500 kW of electric power.

Simon-Carves can design and build OT boilers for operation above, at or below the critical pressure, with steaming capacities for all purposes from small industrial plants to the largest central power stations.

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Simon-Carves Ltd

SIMON ENGINEERING GROUP

STOCKPORT ENGLAND

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SC208

This is the M.R.2 Blast Furnace refractory – a very special brick indeed. It was developed for one application – the lining of Blast Furnaces operating on lean ores – with 100% sinter – and driven hard. M.R.2 is an extremely hard, low porosity refractory to enable it to resist the abrasive effect of the sinter. It is completely unaffected by carbon monoxide and is manufactured from very carefully selected raw materials prepared and moulded under the most stringent control with a final kilning at temperatures of the order of 1600°C to ensure complete volume stability at normal Blast Furnace operating temperatures. This is a brick with a narrow market, but it is typical of the way the Chemists, Physicists and Engineers at Neston look upon the making of refractories – as a branch of precise chemical engineering. Amongst the other things they make with equal care are M.R.1 and M.R.60 bricks and special shapes; low-heat storage insulating refractories M.I.28, and the whole range of Tri-Mor Mouldables and Castables for Monolithic linings which are having such a profound effect on all classes of furnace design.

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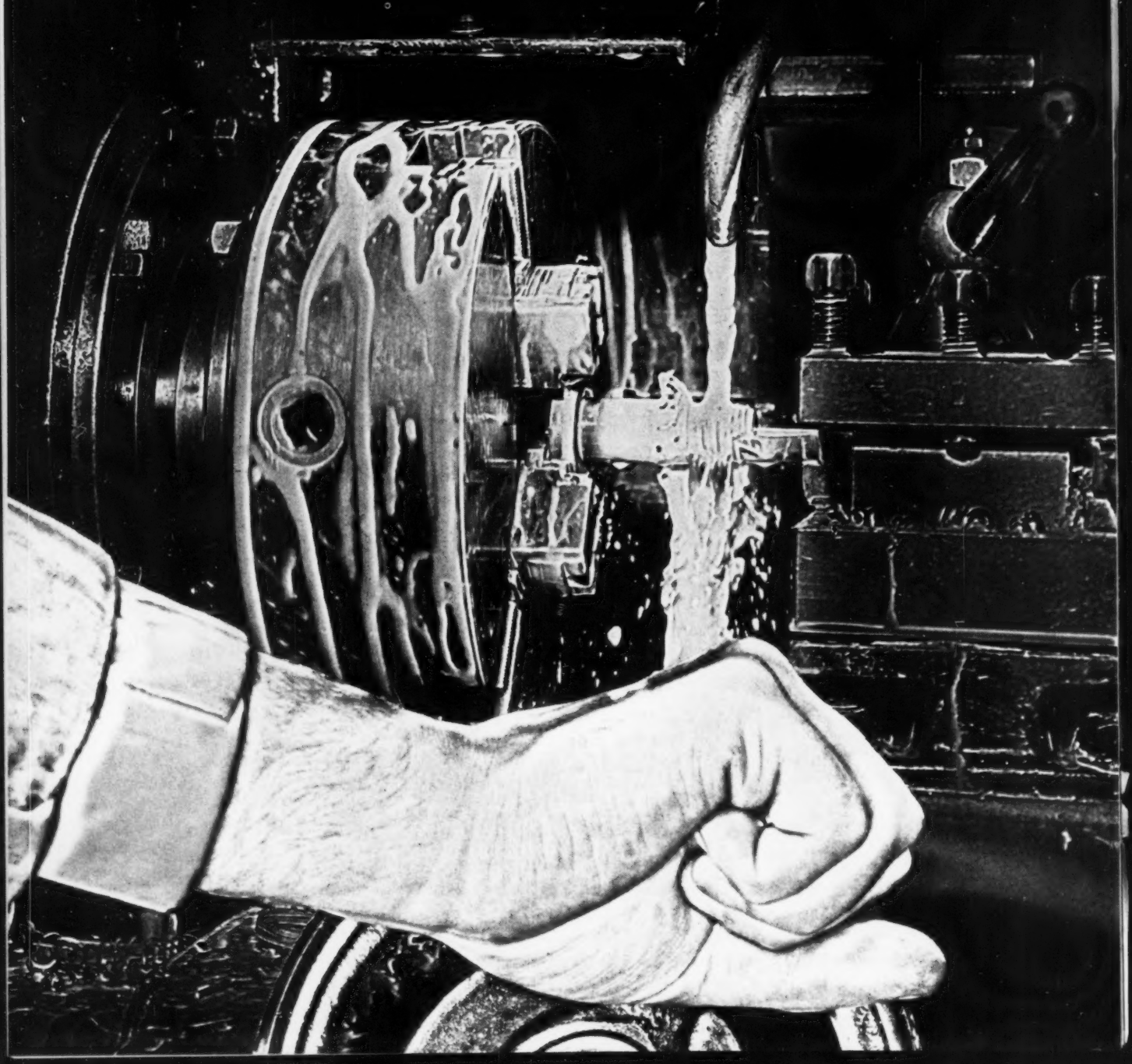


With new Shell Dromus Oils

Most modern soluble cutting oils contain phenolic compounds used as coupling agents between the oil and the emulsifier, for better blending and easier mixing. These phenolic compounds can cause skin irritation, especially where modern high-speed machines are used and the emulsion can concentrate, through the evaporation of water, above the safety level.

Shell research chemists have been working on this problem, which has been causing some concern to Management. After considerable research, Shell Dromus Oils have been reformulated and these new cutting oils now produce bland emulsions, which considerably reduce the risk of skin trouble to operators.

The real difficulty was to find a new coupling agent to replace the phenolic compounds, and Shell finally used what their chemists know as a higher fatty alcohol complex. This solved one problem, but presented another. The new coupling agent was volatile at the high temperatures normally used in blending processes. Further research found a solution to this problem by designing and installing new plant.

The new Dromus Oils are every bit as efficient as before and cost no more. They put Management in the welcome position of being able to minimise working hazards at no extra cost. And machine men need no longer be so worried about skin troubles.

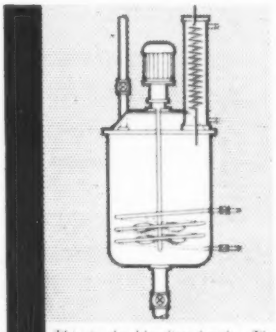
The moral of the story is that Shell research is supremely applicational. The centre at Thornton is always ready to work with even the most specialised sectors of industry to produce the right oil for the job. If you and your organisation have any major lubricating problems, it pays to get in touch with your local supplier of Shell Industrial Lubricants.

The Research Story

Shell chemists in the U.K., in Holland and in the U.S.A., prepared and examined hundreds of experimental soluble oils, and established that certain combinations of fatty alcohols could be used in place of phenolic compounds with no loss of efficiency. They set to work to discover the best combination and developed a higher fatty alcohol complex which fitted exactly. Then they realised that to blend this new coupling agent into soluble oils would require special plant and new blending techniques.

Exhaustive testing of blend stability, emulsion stability, anti-corrosion and machining properties led to selection of the most promising blends. A pilot plant was set up to produce batches of these for use in field trials.

This field testing and final development proceeded for two years whilst production plants were erected at points so chosen as to give the most economical and rapid delivery throughout the United Kingdom.



This is the blending kettle. The reflux condenser beside the stirrer motor prevents the loss of constituents volatile at the blending temperature.

NEW SHELL DROMUS SOLUBLE CUTTING OILS

another proof of Shell leadership in lubrication

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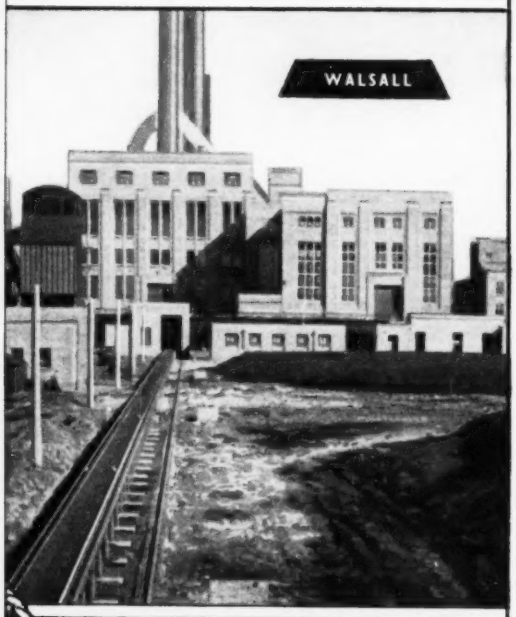

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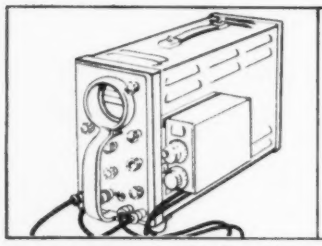
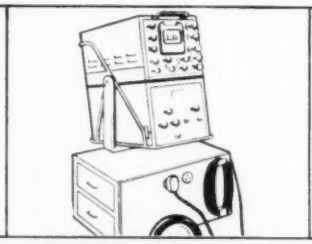
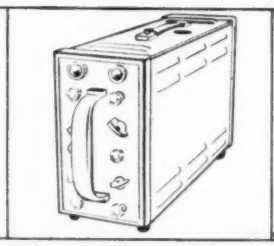


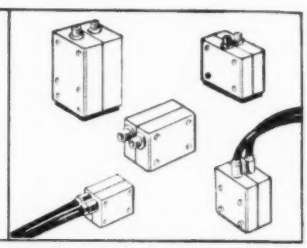
Flaw Detectors, Marks 5F, 5AF. *Portable instruments with similar basic specifications. The 5F is a multi-frequency instrument for use with twin or separate type probes, whilst the 5AF, a single frequency instrument, either 1½, 2½ or 5 Mc/s. Also operates with single type probes. (Shown with Depth Gauge attachment).*



Flaw Detector Mark 6. *Trolley mounted transportable equipment, very powerful and versatile for use with all types of probes and having an exceptionally wide frequency range and high sensitivity.*



Two-Channel Flaw Alarm. *For use with Mark 5 instruments, a portable auxiliary unit providing semi-automatic monitoring facilities which identify and give warning of significant defects.*



Probes. *Extensive development by Kelvin Hughes has resulted in a range of standard probes having either single, twin or separate transducers, and a very high performance throughout.*

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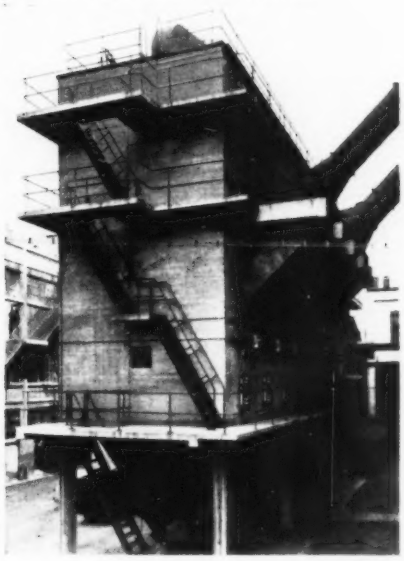

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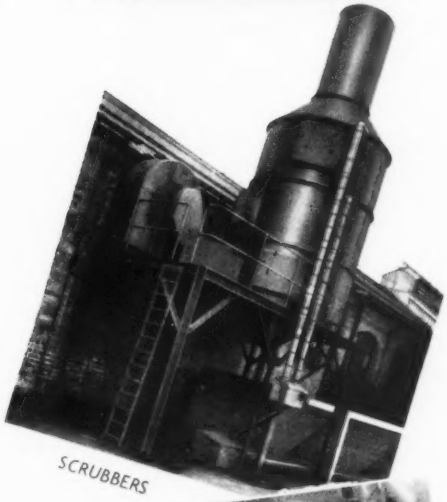
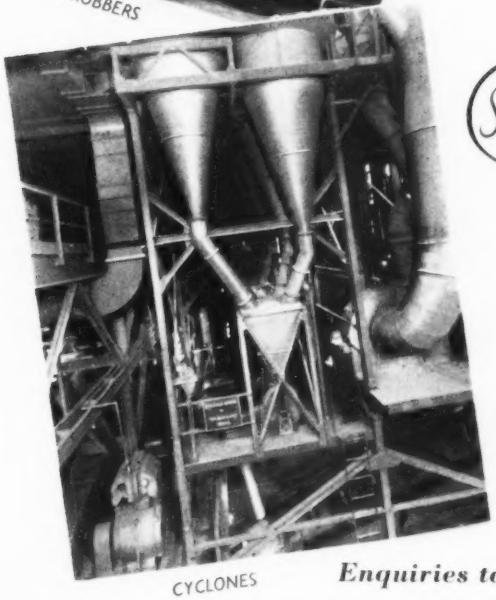


SCRUBBERS



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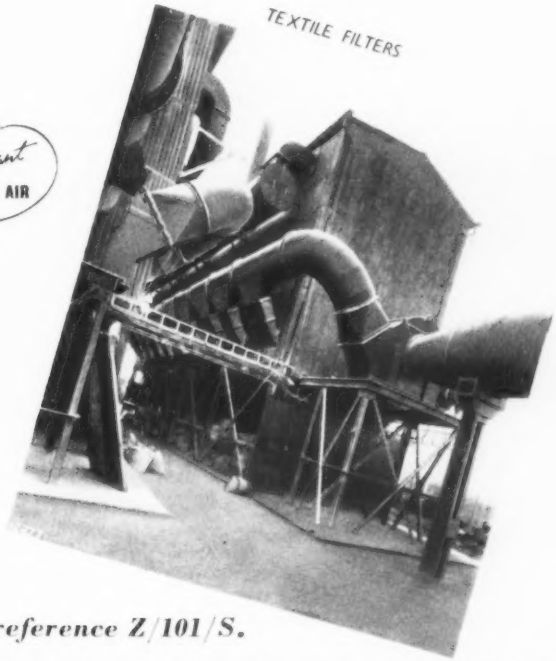

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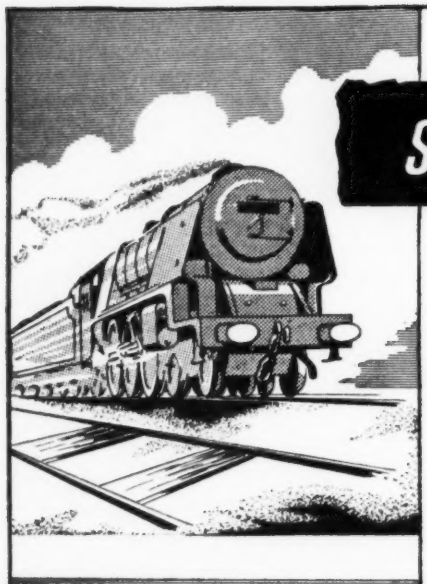

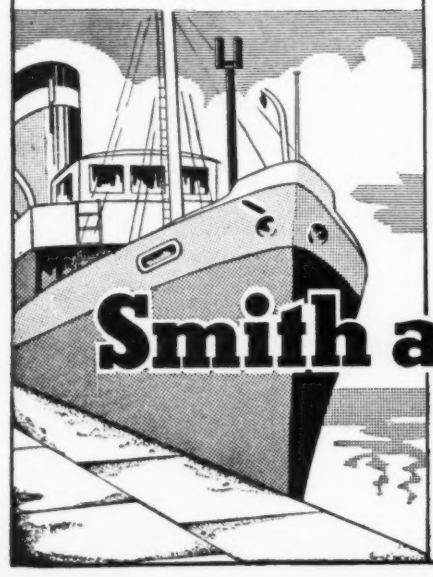

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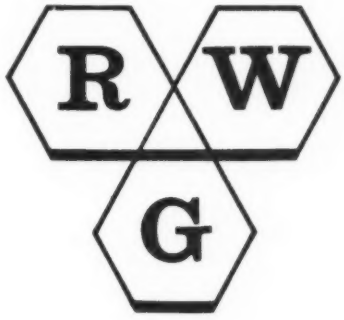

MULTAN GAS TURBINE

Power for Pakistan

At Multan, the first of two gas turbines ordered by the Pakistan Water & Power Development Authority, has recently begun to deliver electrical power. The gas turbine unit is operating on natural gas, but has been designed to run also on gas oil. The nominal rating of the unit is 5,700 kW with an ambient temperature of 40 C; but the alternators are designed for a larger output to take advantage of the extra power which can be generated at lower ambient temperatures. With an ambient temperature of 18 C, an actual output of 7,400 kW has been obtained.

The second gas turbine, originally intended for Multan, is now to be installed at Hyderabad. Erection of this unit will commence shortly and it will be in service later in the year.

Both units - which are identical - were built in the works of Richardsons Westgarth (Hartlepool) Ltd., to Brown Boveri designs. At Hartlepool, Richardsons Westgarth also produce steam turbo-alternators for public electricity supply and industrial use, axial and centrifugal blowers and exhausters to Brown Boveri designs, water-tube boilers of Foster-Wheeler design, Economic type boilers, feed heaters, condensers, rotary cooling-water strainers . . . in fact all the major equipment for power stations.

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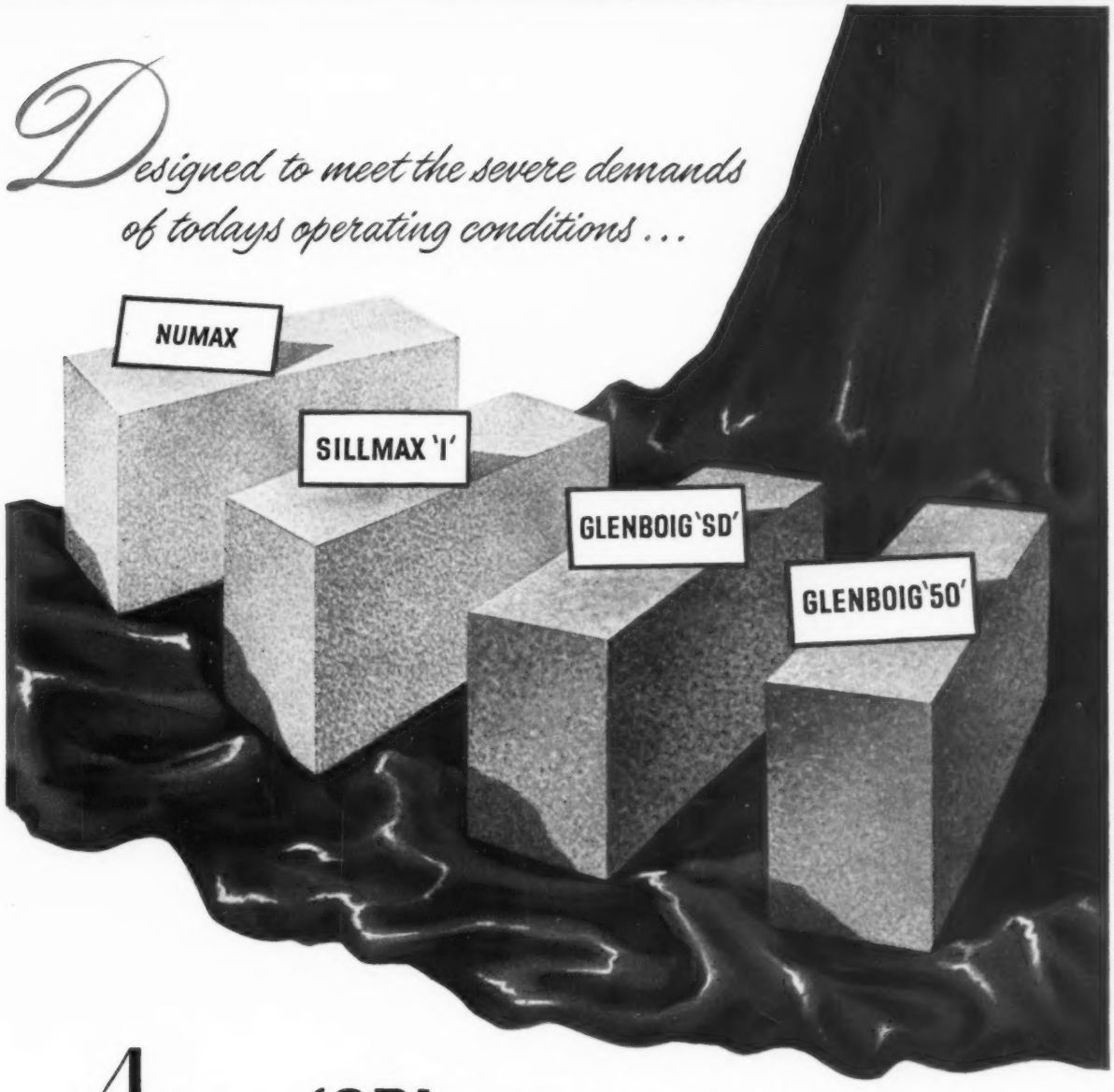

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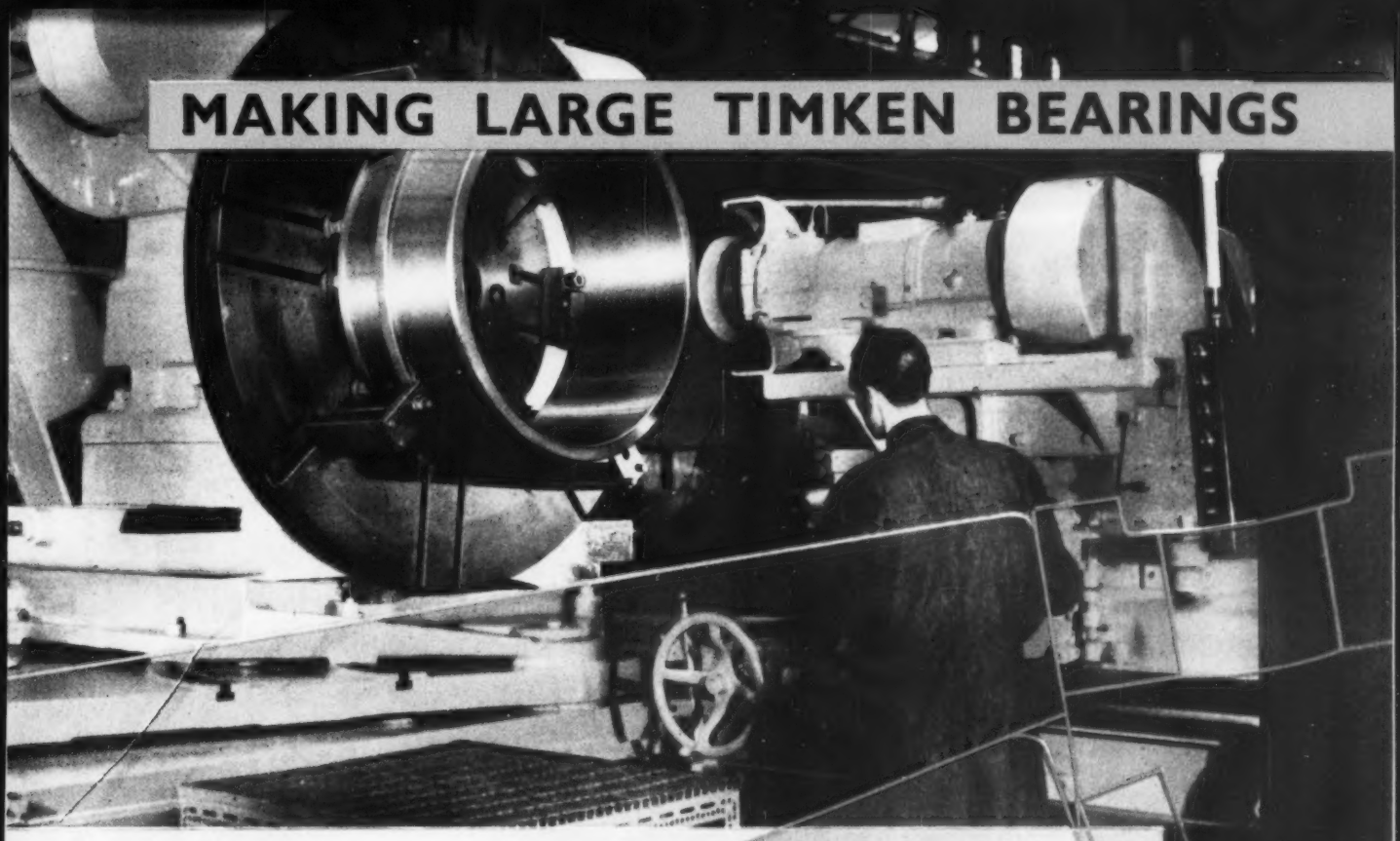

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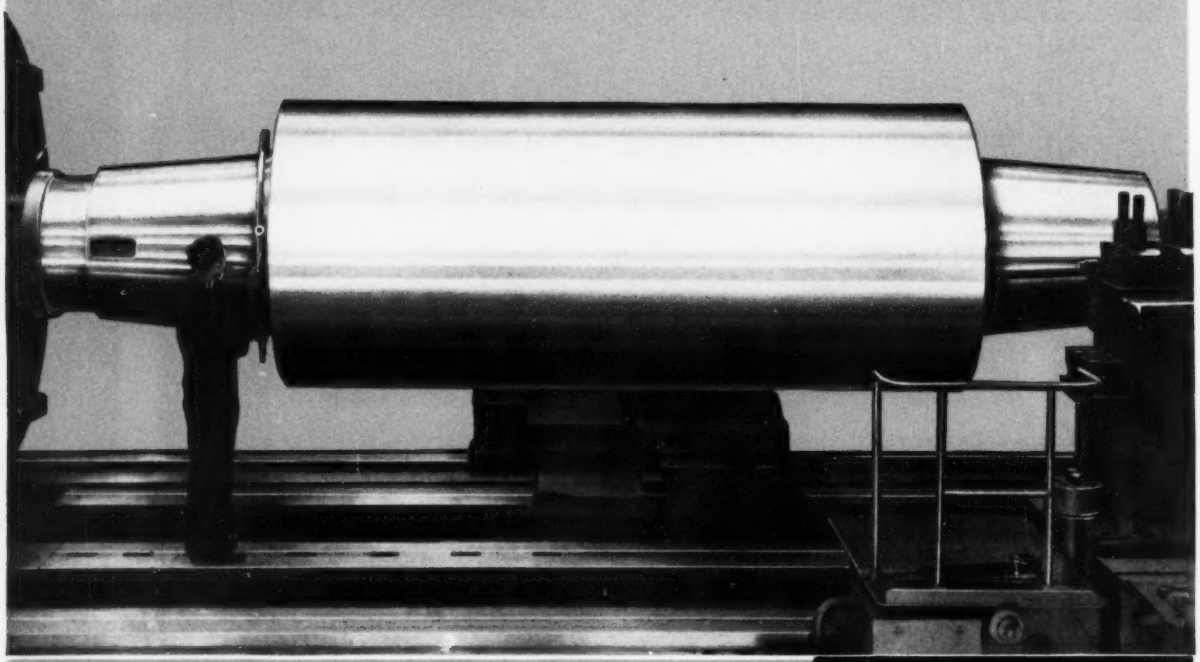
Arbour 44″ O/D × 12′-6″ Long on barrel × 23′-1½″ O/L
Finished machined and fitted with Forged
Alloy Steel Sleeve 63″ O/D × 44″ I/D × 12′-6″ Long.
Sclerescope Hardness 45/50° completed weight 72 tons 19 cwts.



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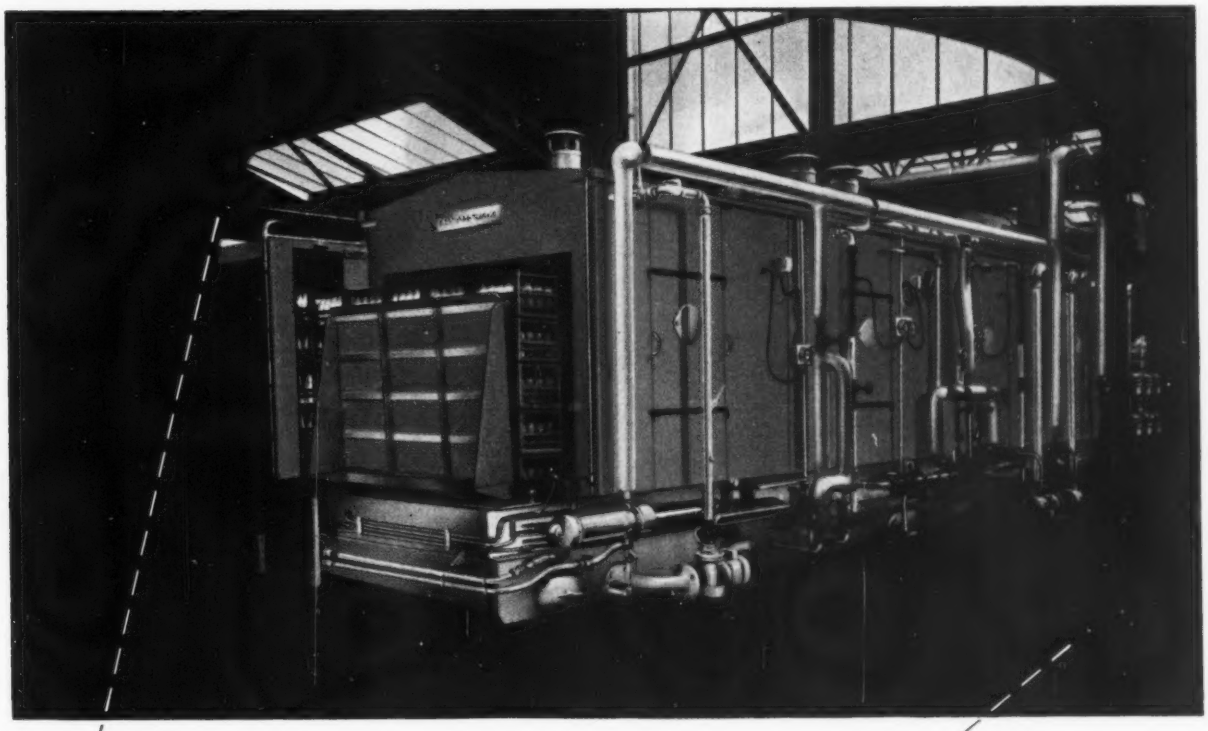

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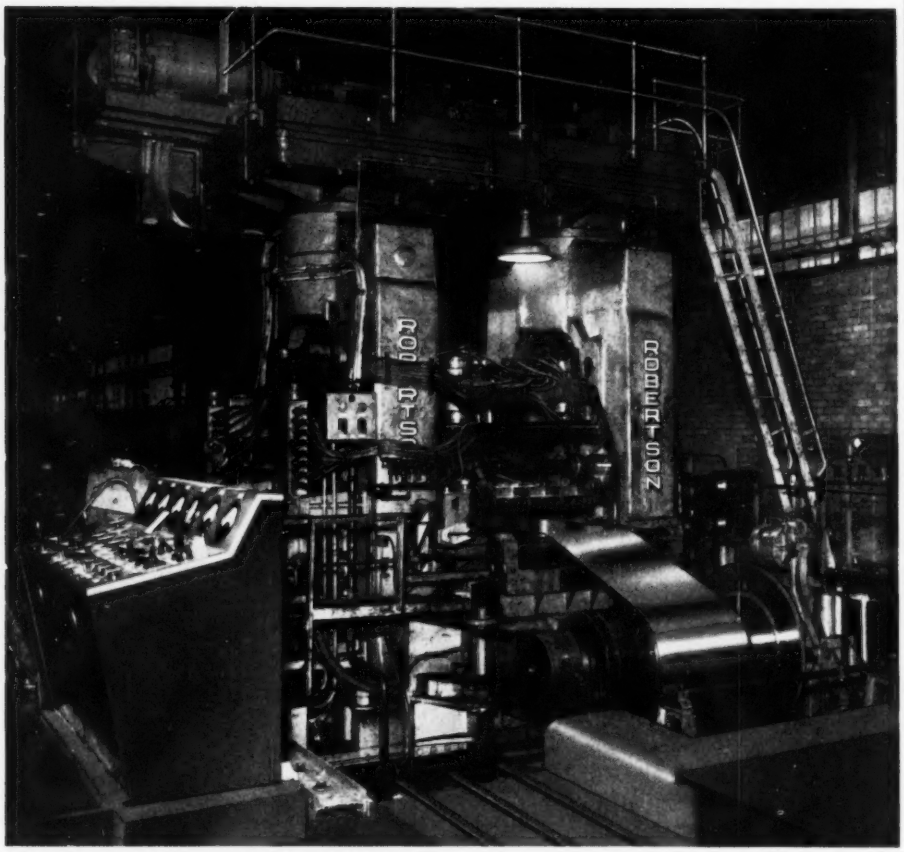

Illustration shows a 15" and 37" × 60" Reversing Four-high Cold Rolling Mill for soft, and alloy steel strip up to 50" wide. Maximum rolling speed 1,200 ft./min.

Photograph by courtesy of Messrs. Richard Thomas & Baldwins Ltd.

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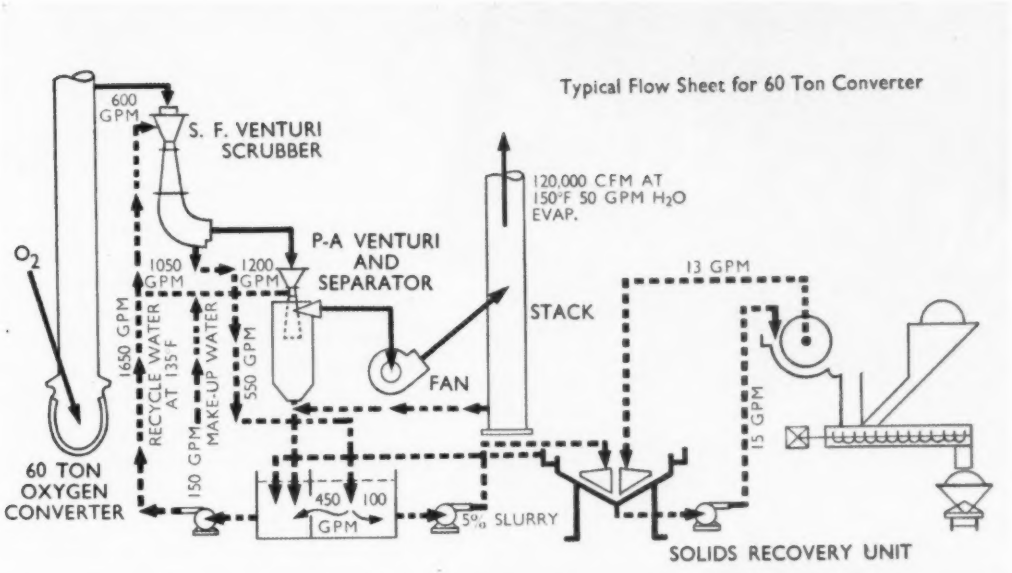

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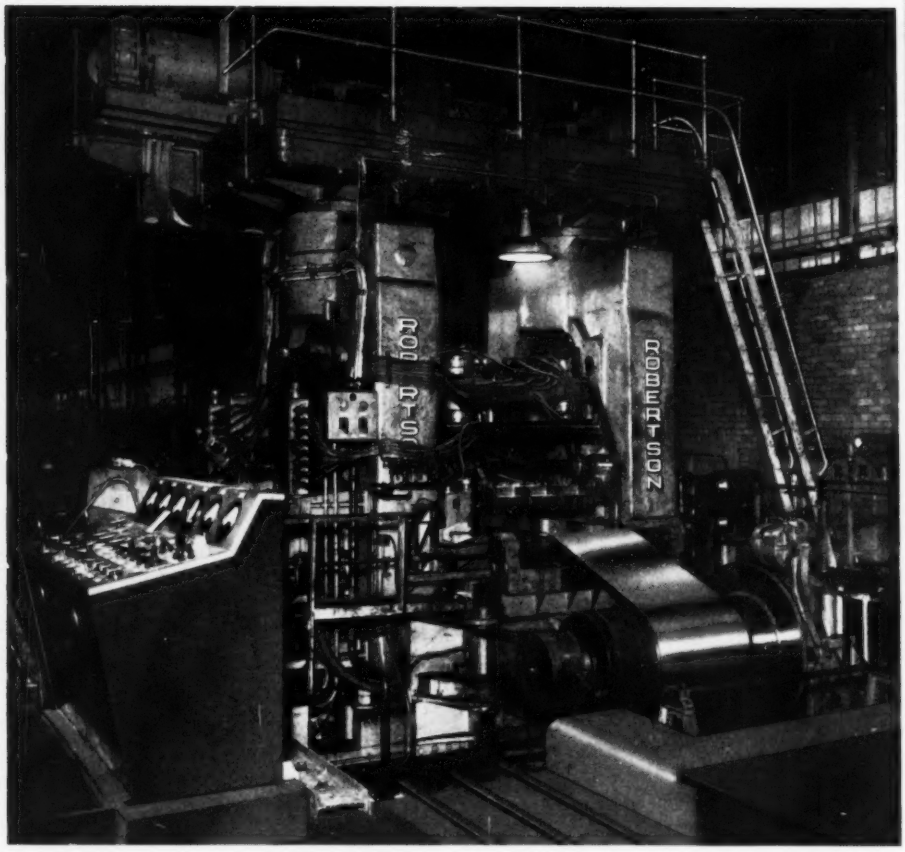

Illustration shows a 15″ and 37″ × 60″ Reversing Four-high Cold Rolling Mill for soft, and alloy steel strip up to 50″ wide. Maximum rolling speed 1,200 ft./min.

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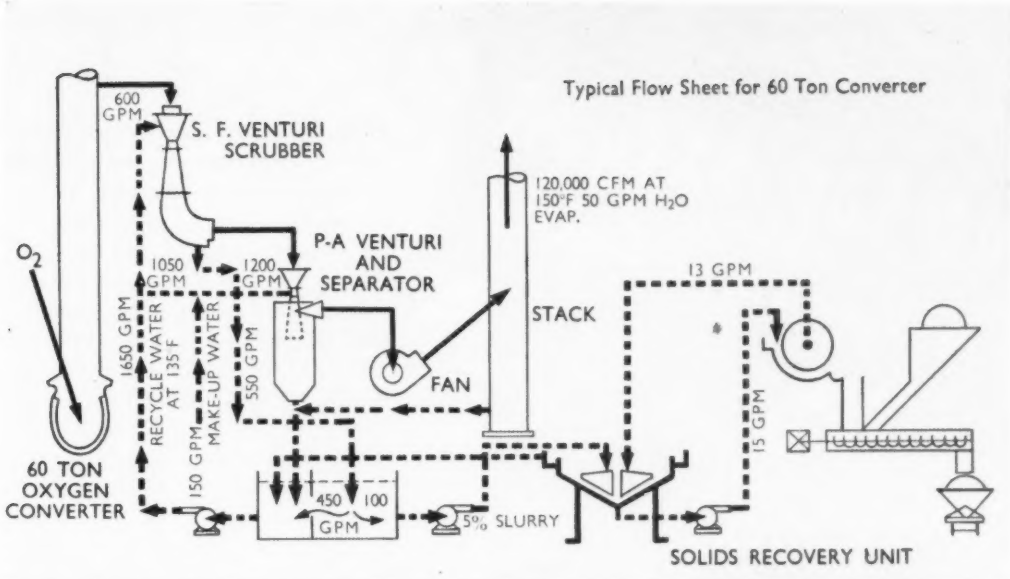

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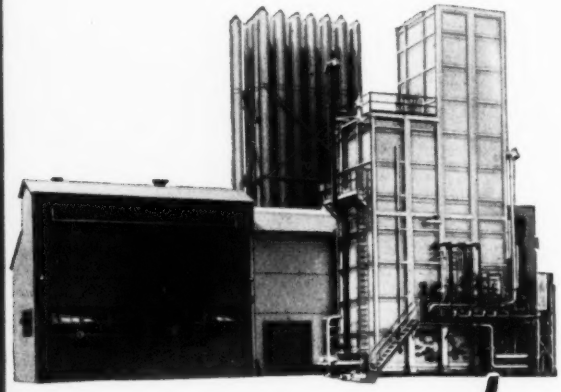

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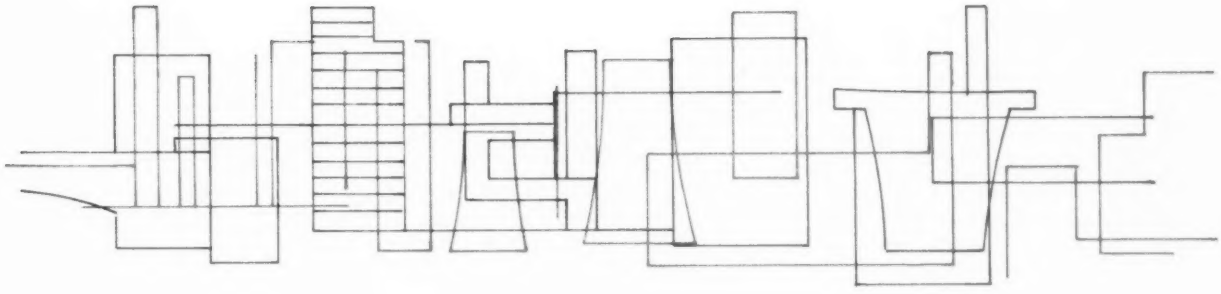

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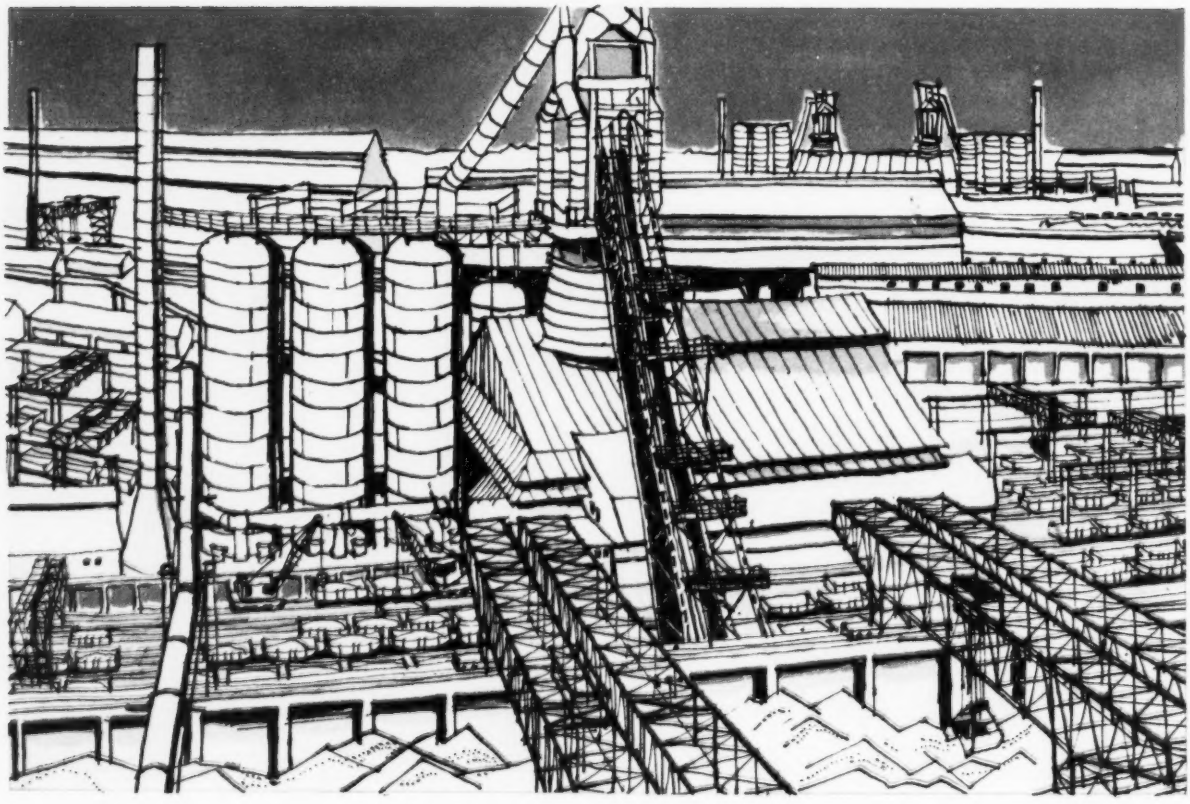

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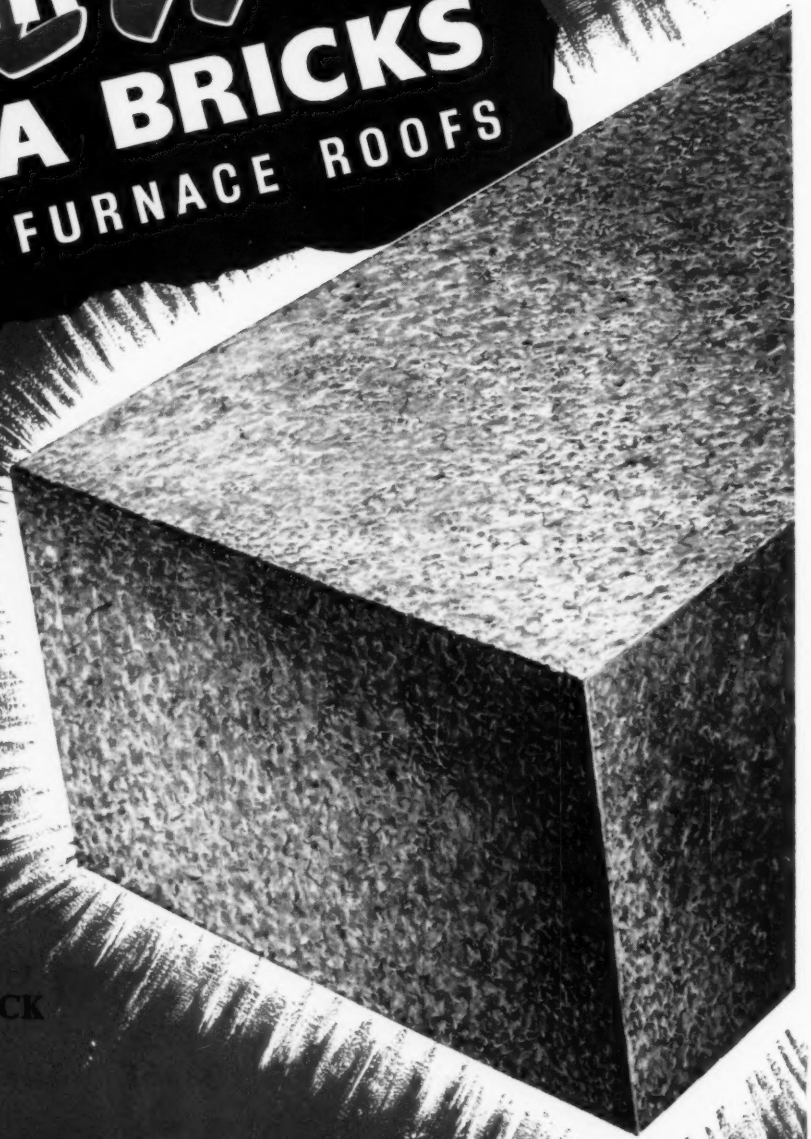

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SLOane 0061
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Professor HERMANN SCHENCK, Dr-Ing., Dr-Ing. E.h.

HERMANN SCHENCK was born in Marburg an der Lahn, Germany, in 1900, the son of Professor Dr Rudolf Schenck, an authority on physical chemistry. Hermann Schenck studied at Münster University and the technical colleges in Breslau and Aachen, and was awarded a distinction in the Diplom-Ingenieur examination in 1923. From 1923 to 1927 he was a scientific assistant, first in the Chemical Institute of Münster University, then in the Institut für Eisenhüttenwesen of Aachen Technical College under Professor Dr Paul Oberhoffer. In 1927 his doctor's thesis 'Theoretical and practical investigations of the deoxidation of iron with manganese', was awarded a distinction.
In 1928 he entered the research department of Fried. Krupp AG in Essen, as an assistant. Two years later he became steelworks engineer in various works of the same firm until his appointment as manager of the open-hearth plant in Essen Borbeck. In 1937 he became works manager of the Charlottenhütte works of the Hüttenwerke Siegerland AG in Siegen and from there he went in 1942 to the Bochumer Verein für Guss-stahlfabrikation AG, Bochum, as technical director and member of the board of management.
He remained there until 1951 when he accepted a professorship at the Rhine-Westphalia Technical College, Aachen, and became director of the Institut für Eisenhüttenwesen, where his field of research and teaching has been wide. Since 1950 he has been President of the Verein Deutscher Eisenhüttenleute.
Of his many published scientific and technical works, first place should be given to his book 'Introduction to the Physical Chemistry of Iron and Steel', which was written in 1932–4. This was the first book ever to deal with the problems of liquid iron and steel and their interaction with slag, and thus Professor Schenck was one of the first to try to synthesize the whole field of steelmaking reactions from the thermodynamic viewpoint. The book was afterwards translated into English and Italian. The English edition translated by Dr H. J. Goldschmidt was published in 1945 by BISRA.
Professor Schenck's contributions and services to the iron and steel industry in many parts of the world have been widely recognized: he is an Honorary Member of the American Society for Metals, the American Institute of Mining and Metallurgical Engineers, the Iron and Steel Institute of Japan, and the Société Française de Métallurgie. He was awarded an Honorary Doctorate in 1958 by the Berlin Technical University, and in 1959 the Société Française de Métallurgie presented to him the Grande Médaille Floris Osmond. This year the Council of The Iron and Steel Institute showed its appreciation of Professor Schenck's work by awarding him the Bessemer Gold Medal, in recognition of his distinguished contributions to metallurgical research, and with special reference to his pioneer investigations into the physical chemistry of steelmaking.

Professor Hermann Schenck, Dr-Ing., Dr-Ing. E.h.

Bessemer Gold Medallist 1960

Autumn General Meeting, 1959

The Autumn General Meeting of The Iron and Steel Institute was held on Wednesday and Thursday, 2 and 3 December 1959, at the Great Hall, Caxton Street, London SW1, with the President, Mr W. Barr, O.B.E., *in the Chair.*

Minutes of the previous meeting

The minutes of the previous meeting held in London on 6 and 7 May 1959 were taken as read and confirmed.

Deaths

The **President** announced with regret the death of 23 Members since the last meeting. The meeting stood in silence.

Announcements

The **Secretary** (Mr K. Headlam-Morley) made the following announcements:

Changes on the Council since the last General Meeting in May 1959:

Hon. Members of Council

Col. W. H. Mather, O.B.E., T.D., President of the Cleveland Institution of Engineers, in place of Mr T. H. Stayman.

Mr W. B. Williams, President of the Ebbw Vale Metallurgical Society, in place of Mr P. Edwards.

Mr J. D. Townsend, President of the Lincolnshire Iron and Steel Institute, in place of Mr A. H. Norris.

Dr E. F. Emley, President of the Manchester Metallurgical Society, in place of Mr Johnson Y. Davies.

Mr H. Edwards, President of the North Wales Metallurgical Society, in place of Mr H. Brooke Freeman.

Mr L. W. Law, President of the Staffordshire Iron and Steel Institute, in place of Mr W. H. B. Wesson.

Mr D. W. Hopkins, President of the Swansea and District Metallurgical Society, in place of Professor R. Higgins.

Mr J. W. Todd, President of the West of Scotland Iron and Steel Institute, to succeed Dr H. Harris.

Retiring Members of Council

The following are due to retire at the next Annual General Meeting and are eligible for re-election:

Vice-Presidents: Mr D. A. Oliver, Mr N. H. Rollason, and Sir Charles Goodeve.

Members of Council: Dr J. H. Chesters, Mr F. B. George, Mr W. F. Gilbertson, Dr L. B. Pfeil, and Mr R. F. Summers.

Mr G. H. Johnson has been elected an Honorary Vice-President of the Institute and Mr P. Holloway has been elected a member of the Council of the Institute.

Andrew Carnegie Scholarships

The following awards have been made since the last General Meeting:

£400 to K. Farrell (Sheffield University) (2nd grant) to assist research on 'The hydrogen embrittlement of ultra-high-tensile strength steels'.

£200 to T. B. Gibbons (Royal College of Science and Technology, Glasgow) to assist research on 'The solubility and activity coefficient of CaS in the CaO–Al_2O_3–SiO_2 system'.

£400 to T. Gladman (Sheffield University) (3rd grant) to assist research on 'The effect of hydrogen on the transformations in alloy steels'.

Dates of Meetings in 1960

(i) Annual General Meeting in London from Tuesday to Thursday, 3–5 May, to include a symposium on wide strip. Dinner for members on Wednesday 4 May.
(ii) Joint Meeting on 'The determination of gases in metals' on 3 and 4 May, organized by the Society for Analytical Chemistry in conjunction with The Iron and Steel Institute and the Institute of Metals.
(iii) Special Meeting in Italy on 29 May to 10 June, by invitation of the Associazione Italiana di Metallurgia.
(iv) Autumn General Meeting in London, Wednesday 30 November and Thursday 1 December.

There was a telegram of greetings from the Italian Chemical Society.

President-Elect

The **President** proposed, on behalf of the Council that Mr W. F. Cartwright be nominated for election as President, to take office at the Annual General Meeting in 1960 and to serve for one year. Mr Cartwright joined the Institute in 1936, was a member of Council in 1946, Vice-President in 1955, and Bessemer Medallist in 1958. He had also been active in the Engineers Group.

Election of Members

Mr F. Houghton and Mr F. A. Batty, scrutineers of the ballot, reported the following elections:

MEMBERS

Adams, Austin Thomas (Dowlais); **Adamson,** Murdoch Hugh, A.I.M. (Stillington); **Allen,** Richard Gordon (Newcastle-upon-Tyne); **Allison,** Robert William, B.SC.(ENG.) (Cardiff); **Atkin,** Eric A. (Scunthorpe); **Atkinson,** Raymond Frederick, B.SC.(HONS.MET.) (Manchester); **Baker,** Dexter Farrington, B.S.MECH.ENG. (London); **Ball,** Derrick Frank, B.SC. (Old Aberdeen); **Barequet,** David, B.SC., DIPL.ING., A.R.C.S.T. (Haifa, Israel); **Bateman,** Percy R., T.D. (London); **Baynes,** Alan David, A.MET., L.I.M. (Rotherham); **Beam,** Donald C. (Toronto, Ontario, Canada;) **Bean,** George William (Burnley); **Beese,** John Gaythorne, B.SC., L.I.M. (Cardiff); **Beissel** Frank Eric, A.I.M. (Nunawading, Victoria, Australia); **Bengtson,** Waldemar (Västeras, Sweden); **Black,** Charles W. (Glasgow);

Braddel, Harry Arthur (London); **Brick,** Robert M., PH.D., MET.E. (Chicago, Ill., USA); **Bulman,** Frederick, A.M.I.MECH.E. (Workington); **Burrows,** Stanley, A.M.C.T. (Hyde); **Campbell,** David Benbow, B.SC., MECH.ENG., G.I.MECH.E. (Coatbridge); **Carter,** William Alfred, G.I.MECH.E. (Brierley Hill); **Chatteraj,** Amborish, B.SC. (Clausthal-Zellerfeld, West Germany); **Chavarri, Poveda** Gabriel De (Bilbao, Spain); **Childs,** Wylie J., M.MET.E., PH.D. (Troy, N.Y., USA); **Churcher,** T. C., B.SC., A.R.I.C. (London); **Clark,** Brian Dennis, M.INST.F. (London); **Clifton,** Peter Vincent, M.A., D.PHIL. (London); **Craig,** John Hopper, A.R.C.S.T. (Glasgow); **Cummins,** Francis George (London); **Darbishire,** A. T., B.ENG., A.M.I.MECH.E. (Richmond); **Dartois,** Robert (Moustier-sur-Sambre, Belgium); **Daubersy,** Jean (Liège, Belgium) **Dave,** C. J., B.E.MET.(HONS.) (Calcutta 13, India); **Davies,** Jared Marshall, A.I.M. (Merthyr Tydfil); **Davis,** Alfred (Glasgow); **Dean,** Ronald (London); **De Havilland,** Major-General Peter Hugh, C.B.E. (London); **Dennison,** Donald B.SC.(HONS.MET.) (Newcastle-upon-Tyne); **De Young,** H. George, B.SC.ENG. (Welland, Ontario, Canada); **Driscoll,** James, B.A.(HONS.) (London); **Duncan,** Thomas Kenneth, B.ENG. (Wollongong, N.S.W., Australia); **Easterbrook,** Eric John, B.SC.(ENG.), A.R.S.M. (Whitchurch); **Edgar,** John, B.SC. (Scunthorpe); **Edwards,** Alan Morrison, A.MET. (Moorgate); **Egré,** Pierre (Paris, France); **Erasmus,** Leslie Andrew, B.SC.(MECH.ENG.) (Sheffield); **Ertl,** Dietrich, DR.-ING. (Frankfurt (Main), Germany); **Evans,** Archibald Arthur (Port Talbot); **Ewing,** Arthur F., B.A. (Geneva, Switzerland); **Farrer,** Sydney, M.SC.(TECH.), M.I.E.E., A.M.I.MECH.E. (Turnbridge); **Fasciato,** Victor Vincent (Sheffield); **Ferguson,** Ian Andrew, DIPL.R.T.C., M.I.E.E. (Rugby); **Finch,** Norman Arthur (Wrexham); **Finkl,** Charles William, B.S.(MECH.ENG.) (Chicago, Ill., USA); **Floridis,** Themistocles, P., M.SC., SC.D. (Monroeville, Pa., USA); **Garcia Ramal,** Enrique (Bilbao, Spain); **Gerard,** Marcel (Liège, Belgium); **Gertsman,** Sol Lawrence, M.A. (Ottawa, Ontario, Canada); **Ghosh,** Subrata, PH.D. (Port Talbot); **Goldberger,** Erwin (Buenos Aires, Argentina); **Golding,** William Victor, A.M.INST.T. (Middlesbrough); **Gonni,** Massimo (Milan, Italy); **Gray,** Norman (Middlesbrough); **Greenwell,** Rose (Middlesbrough); **Gregory,** Bernard, B.SC.TECH., PH.D., A.M.C.T., A.I.M. (Manchester); **Gregory,** Jack (Sheffield); **Gronow,** Clive (Middlesbrough); **Gruber,** Kurt, DR.ING. (Gladbach/Rheinland, Germany;) **Guerlin,** Jean-Daniel (Paris, France); **Gunst,** P. M. (IJmuiden, Holland); **Gwyther,** David Nigel, B.SC., A.M.INST.GAS.E., A.M.INST.F. (Consett); **Hawken,** William Anthony, G.I.MECH.E. (London); **Hayward,** Elwyn Ronald, B.SC., PH.D. (Birmingham); **Hedges,** Derek Alexander, A.M.I.MECH.E. (London); **Heyes,** George Brice (London); **Hill,** Holgate, A.MET. (Scunthorpe); **Hirase,** Masakazu, B.ENG. (Tokyo, Japan); **Hoedemakers,** Caspar Jacobus Petrus (The Hague, Holland); **Huber,** Walter (Winthertur, Switzerland); **Hunt,** Norman, A.M.I.MECH.E. (Wednesfield); **James,** John Mansel (London); **Janssens,** Vincent (Liège, Belgium); **Jarman,** Graham Thomas (Alperton); **Joeres,** Paul, DIPL.ING. (Gladbach, Germany); **Johannsen,** Kermit L., (Fairless Hills, Pa., USA); **Johnson,** James, B.SC. (Manchester); **Johnson,** Robert J., B.SC. (New York, N.Y., USA); **Jones,** John J. (Dowlais); **Jones,** John Tudor, A.M.I.E.E. (Stafford); **Jongenburger,** Petrus (Delft, Holland); **Keen,** Gordon, B.MET., A.I.M. (Kiveton Park); **Keen,** Thomas Henry (Cardiff); **Keith,** Ronald Stewart (London); **Kendall,** E. Homer (Alliance, Ohio, USA); **Kennedy,** Ralph Grant, B.S., M.A. (Cleveland, Ohio, USA); **Koetem,** Klaas (Rotterdam, Holland); **Legrand,** Augusto H. (Buenos Aires, Argentina); **Lewis,** Richard William (Dowlais); **Lewis,** Stanley Charles Edward (Oxford); **Long,** Charles Trevor, B.SC.(ENG.) (Pretoria, Transvaal, S. Africa); **Lowe,** James Austin (Preston); **Lyth,** Charles, B.SC.(HONS.MET.) (Weybridge); **Mann,** David John Oswald, B.A. (Scunthorpe); **Matthew,** Thomas U., PH.D., M.SC., A.R.T.C. (Brierley Hill;) **Michaelis,** Dr Eduard (Vienna, Austria); **Millar,** William D. (Fairless Hills, Pa., USA); **Millard,** Maxwell D. (Pittsburgh, Pa., USA); **Mills,** John Eric (Sheffield); **Mittal,** Om Prakash, B.SC.(MET.ENG.) (Nakur (Dist. Saharanpur), UP, India); **Maocelio de Aguiar Mendes,** Manoel (Gerais, Brazil); **Nekervis,** Robert J., E.MET. (Columbus, Ohio, USA); **Nijman** D. G. (IJmuiden, Holland); **Noon,** Jack Colin (Birmingham); **Pagnamenta,** Charles Francis, O.B.E. (Cardiff); **Pancino,** Renato, DOTT.ING. (Milan, Italy); **Parish,** Alan Raymond, B.SC.(ENG.), A.M.I.E.E. (London); **Parkes,** A. R. (London); **Petiet,** Marcel (Paris, France); **Peto,** Jean-Claude (Paris, France); **Pfeiffer,** Claes Fredrik Hakan (Stockholm, Sweden); **Posthuma,** F. (Rotterdam, Holland); **Pott,** Gilbert, B.SC.(ENG.), A.M.I.C.E., A.M.I.MECH.E. (Workington); **Pratt,** Richard Kenneth (Hebburn-on-Tyne); **Priest,** Frederick Ronald (Middlesbrough); **Prosser,** Deryk Phillip Burton, M.A., A.M.I.C.E., A.M.I.E.E. (Rotherham); **Prosser,** William Howell, B.SC. (Dowlais); **Radigues,** Jacques de (Liège, Belgium); **Rafferty,** George (Thornaby-on-Tees); **Rakover,** M. (London); **Ramm,** David Llewelyn, B.A. (Scunthorpe); **Roberts,** Herbert, A.M.I.MECH.E. (Motherwell); **Rosiund,** Lars (Storforsverken, Sweden); **Rushworth,** Peter John, L.I.M. (Dagenham); **Schnaible,** Harold Williams, M.S., PH.D. (Monroeville, Pa., USA); **Schneider,** Philipp, DIPL.ING. (Düsseldorf-Grafenbert, Germany); **Skellington,** Gordon Gray (Sheffield); **Smith,** William James Burling, A.I.M. (Birmingham); **Spanswick,** John Roland, B.SC.(ENG.), M.I.E.E., M.I.MECH.E. (Stafford); **Speith,** Karl Georg, DR.-ING. (Duisburg-Huckingen, Germany); **Stacey,** Francis Ernest, A.M.I.MECH.E. (Scunthorpe, Lincolnshire); **Sturdy,** Clifford, M.A., A.M.I.MECH.E. (Sheffield); **Sundaram,** N., B.SC. (London) **Swain,** John Arthur (Birmingham); **Tattersall,** Norman (Middlesbrough); **Thomas,** Arthur Norman (Middlesbrough); **Thomas,** Graham Hugh (Saltburn-by-the-Sea); **Upton-Kemp,** Eric, T.D., F.R.I.C.S. (London); **Venn,** Roland John, T.D., M.I.CHEM.E., ASSOC.I. MECH.E. (London); **Ventafridda,** Vincenzo (Milan, Italy); **Walker,** Lester R. (Fairless Hills, Pa., USA); **Ward,** Herbert Frederick (Port Talbot;) **Weiler,** Georg E., DIPL.-ING. (Koln-Bayenthal, Germany); **Werner,** Hermann, DIPL.-ING. (Frankfurt (Main), Germany); **While,** Dennis Aubrey (Barrow-in-Furness); **Whitehead,** Thomas Charles Gill, B.SC.(CHEM.), A.R.I.C. (Middlesbrough); **Wilkinson,** Denis Heaton, H.N.C. (Keighley); **Willey,** Vernon H. (London); **Williams,** Derek William John (Dowlais); **Willis,** Ralph Lloyd, B.SC.(HONS. MET.) (Orkney, W. Transvaal, S. Africa); **Wilson,** Thomas Brian, L.I.M. (Newcastle-upon-Tyne); **Younger,** J. L. (Dowlais).

ASSOCIATES

Akhtar, Mohammad Salim (Wolverhampton); **Cole,** David (Bradford); **Colley,** Andrew Hilton (London); **Crookes,** Alan Frank (Sheffield); **Evans,** David William (Sheffield); **Farrar,** Roy Alfred (London); **Görissen,** Johan Petter, B.MET. (Kristiansand S, Norway); **Hicks,** Richard John, B.SC.(ENG.MET.), A.R.S.M. (Sheffield); **Hotchkies,** Livingstone Mackay, L.I.M. (Welland, Ontario, Canada); **Jakobi,** John Robert, B.MET. (Stoke Mandeville); **Kilpatrick,** John Anthony (Workington); **Leach,** Peter Walter, B.SC.(ENG.)(MET.), L.I.M. (Johannesburg, S. Africa;) **Lewin,** Roger (Sheffield); **Marsh,** Anthony Edward (Sheffield); **Middleton,** Malcolm Cecil, A.MET. (Sheffield); **Moore,** Thomas William (Sheffield); **Morley,** Michael (London); **Newall,** Roger Hargreaves, B.SC.(HONS.)(MET.) (Manchester); **Oxlee,** Colin Hamilton, B.SC.(MET.) (Westbridgford); **Phillips,** John William Burbridge (Newcastle-upon-Tyne); **Pollock,** Derek David John, L.I.M. (Nottingham); **Richinson,** Peter John, B.MET. (Leicester); **Sargent,** Gordon (Scunthorpe); **Sarkar,** Sudhin, B.SC. (Sheffield); **Smart,** Ernest, L.I.M. (Sheffield); **Stanley,** Robert Edward (Birmingham); **Sundarrajan,** V. N., B.SC.(HONS.) (Calcutta, India); **Upadhyaya,** Gopal Shankar, B.SC. (Varanasi, India); **Wade,** Richard Harry (Cambridge); **Walker,** Roger Malcolm, B.A. (Rotherham); **Walters,** Cedric Norman, B.A. (London); **Williams,** John Adrian (Swansea).

The **President** declared those candidates to be duly elected. They numbered 195, and the total membership of the Institute was now 5209.

STAL *in English*

Number 11 (November 1959) of the cover-to-cover translation of the Russian journal *Stal'* has been published and no. 12 (December 1959) should appear early in May. Full details of subscriptions to *Stal in English* are available from the Secretary of The Iron and Steel Institute.

Some aspects of steel extrusion

R. Cox, T. McHugh, B.Sc., and F. A. Kirk, A.Met., A.I.M.

SYNOPSIS

The authors describe the steel extrusion plant at Low Moor and show that the process is now firmly established. Some production techniques and extrusion problems are examined. The choice of suitable forms of raw material is discussed and attention is drawn to the advantages to be gained from the low-frequency induction method of billet heating. The tooling of the Loewy 1150-ton press is described and a survey is made of dies and mandrels.

The function of glass lubrication is examined and reference is made to the many factors that influence the dimensions and tolerance limits of steel extrusions, particularly in the case of complex shapes. Products best suited to the extrusion process are listed and consideration is given to future development. The economic potential of extruding continuously cast billets is mentioned and it is intimated that work on this project will be pursued. 1779

ALTHOUGH GREAT PROGRESS has been made since Séjournet's early experimental work on a 600-ton horizontal press, there are still difficulties associated with steel extrusion. In the present paper it is intended to discuss some of these difficulties, together with the various methods adopted by the authors to overcome them. As will be shown, not all of these are concerned with production techniques. There are problems associated with the economics of steel extrusion, but it is the authors' opinion that by close liaison with press designers, equipment can and will be made to solve these.

The commercial development of steel extrusion has been made possible by the Ugine-Séjournet glass lubrication process, which Low Moor Fine Steels Ltd operates under licence from Comptoir Industriel d'Etirage et Profilage de Métaux, Paris, the process being protected by patents granted in all industrial countries of the world.

Before the advent of the glass lubrication process, various lubricants of the graphite and grease type were in use and, indeed, the extrusion of thick-walled stainless-steel tube in the UK has been undertaken for 20 years or more. However, the problems of solid section and finned tube extrusions are more complex and the lubrication requirement is more critical. Moreover, the demand from users is for longer extruded lengths and closer tolerances. These problems are being surmounted by the careful selection of glass and by improved die design.

The press at Low Moor was completed in 1955 and can accommodate an unlimited variety of sections ranging, for example, from simple 1 in. × 1 in. × $\frac{3}{16}$ in. angle to complex shapes falling within a circumscribed circle of $4\frac{1}{4}$ in. dia. Generally tolerances are kept to −0·000 + 0·030 in. for all dimensions, but occasionally larger tolerances are required on individual sections or difficult materials.

A plan of the extrusion shop as at present laid out is shown in Fig.1. From this it will be seen that there are basically six stages of manufacture:

(i) raw-material and billet preparation
(ii) billet heating
(iii) extrusion and tooling
(iv) straightening
(v) pickling
(vi) inspection and despatch.

Raw material is stored near the billet preparation department. Billet preparation usually consists of three operations: (*a*) turning the bar, (*b*) shaping the bar in the lathe at the required billet length, and (*c*) cutting to length on a cold saw.

The billet heating equipment consists of Loewy Magnethermic 50 c/s induction heating coils. There are

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The authors are with Low Moor Fine Steels Ltd.

1 *Plan of extrusion shop*

three heaters, each rated at 437 kVA. Each heater is operated by a separate control panel adjacent to the coil. All movements of the billet on the heater are by individual push-button, or on autosetting. The control panels indicate primary and secondary current, power input, and power factor. To the right of these is the panel containing the Honeywell-Brown controlling and recording instruments. The temperature is measured by means of a Land radiation pyrometer sighted through the coil.

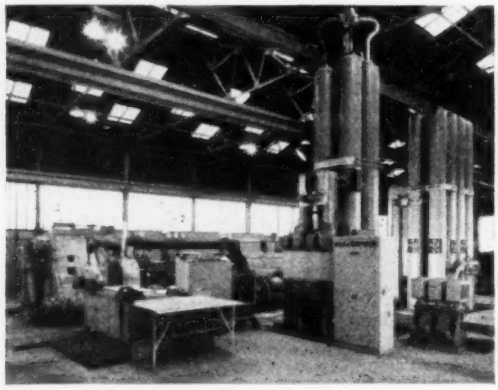
There are three sizes of billet, $4\frac{1}{8}$ in. dia., $5\frac{1}{8}$ in. dia., and 6 in. dia., and to accommodate these there are three interchangeable coils for each heater. Coil changing is a very rapid operation, although this factor is only important when it becomes necessary to change to a coil of the same size because of a fault or breakdown.

The coils, transformers, and flux diverters are all watercooled, using a closed circulating system with automatic make-up for evaporation losses. An interlock is fitted to a water pressure gauge on the main control panel so that in the event of a temporary loss of water pressure the power is automatically switched off.

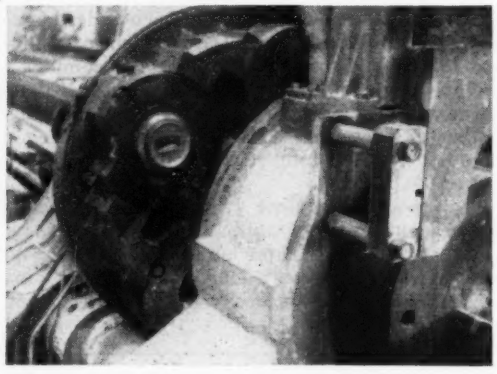
When a billet has been brought to the desired temperature it may be delivered to the press either automatically or by a series of push-button operations. On arrival at the press the billet is automatically 'kicked' off the conveyor and rolls down a glass-covered table into the billet tray in front of the container opening; thence it is pushed into the container by the ram and through the die into the runout table.

The press itself is a three-stage horizontal design by the Loewy Engineering Co. Ltd, the stages being 300, 850, and 1 150 tons. These stages are obtained with the piercer of 300 tons operating inside the main ram of 850 tons. They can be used independently or in tandem to give the maximum force of 1 150 tons. Being of the 3-column type with one column at the apex, changing of containers is made somewhat difficult, and the modern trend is for a 4-column press, or for the 3-column press to be placed on its side.

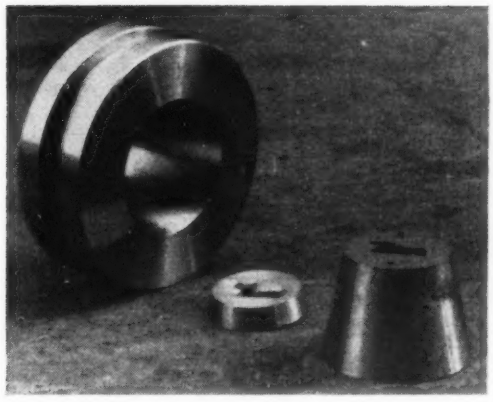
The accumulator system consists of four air-water



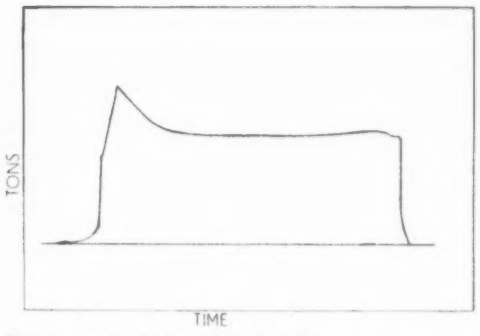
2 *View of accumulator station*



3 *Rotating die carrier*



4 *Die holder, die, and backer*



5 *Pressure curve during extrusion cycle*

bottles (Fig.2) and eight air bottles, the hydraulic fluid being water with approximately ½–1% of soluble oil added. The high-pressure water is delivered to the air-water bottles by two Loewy horizontal pumps of the three-throw type delivering 89 gal/min at a pressure of 2850 lb/in^2. Above the pumps is the water tank from which the water is taken by the pumps for delivery to the air-water bottles. All return flows from the high-pressure side of the cylinders are delivered to this tank. High-pressure water is only used for the pressing stroke; all other movements of the ram are carried out with pre-fill pressure.

Adjacent to the press, and raised very slightly above ground level, is the press operating panel on which are situated the throttle valves for the piercer and main rams. Directly underneath the control panel is the main block housing the control valves. Two levers on the control desk operate respectively the piercer and main rams, and with experience it is possible for the press operator to regulate the ram speeds. On the press being described the maximum free ram speed is in the neighbourhood of 6 in. per second.

Apart from the rams there are three other main items on the press, namely, the platen taking the three columns, the container, and the rotating die carrier (Fig.3). The container, which is a three-unit type and will be discussed in more detail under tooling, moves on its own slides by means of two rams, each having a pull of 75 tons. To overcome the problem of unbalanced loading due to the positioning of the container rams, a torsion bar is incorporated at the rear of the platen. By means of linkages, connexion is made to the container rams, thus ensuring that both move simultaneously, eliminating any inclination for independent movement when sealing on the die. By so doing, a tendency of the container housing to move off the axis of the press has been overcome, resulting in an improvement in concentricity of hollow sections.

Situated on the platen, between the platen and the container, is the revolving die carrier, containing two stations for dies and two for discards. Each movement of the wheel is made through 90° by push-button from the press operating panel. A die and backer are loaded into a die holder (Fig.4) and placed in the die wheel. When this is indexed into position the container closes on to the angled face of the die holder, and the run-out table is moved into position at the rear of the platen.

After the container has closed on to the die holder, the billet table is dropped into position ready to convey the heated billet to the billet tray in front of the container opening. Before this happens, however, the table is covered with a low-melting-point glass powder and an agglomerated glass pad is placed inside the container against the die. The billet is ejected from a heater, rolls down the table into the tray – picking up glass as it does so – and is pushed forward by the pressing stem into the container. The initial stage of the operation is taken up in upsetting the billet to the container diameter and entering it into the die orifice. The specific pressure peak is always noted at this stage, as shown in Fig.5. On completion of the pressing stroke the stem is retracted clear of the container, which is moved back from the die, allowing a high-speed hot saw to swing down and sever the extruded bar from the discard left in the container. To free the extrusion still held securely in the die, the container closes once more up into the die, the two sawn faces butt on one another, and the extrusion is pushed through clear of the die.

The run-out table, which is to the patented design of Comptoir, is then moved away from the platen and deposits the extrusion on the floor plate for any necessary hand-straightening. At the same time the container is moved back and the die wheel rotated through 90°; this allows the discard to be pushed out by another movement of the ram. The die wheel is rotated a further 90° to move the next die into position, which also makes the discard accessible for an operator to collect and separate from the pressure disc. After being brushed with a revolving wire brush to remove scale, glass, etc., the container is then closed on to the die ready for the next extrusion. Between each extrusion the die is taken out and cleaned from scale and glass.

It frequently happens that the shape of the extruded section precludes the possibility of straightening by conventional methods so that, in many cases, the extrusions are straightened on a 200-ton hydraulic stretcher. Most of the glass is cleared from the bars in stretching and this speeds up the next operation, pickling, quite considerably. From pickling, the bars return to the main shop for inspection and despatch.

RAW MATERIALS AND BILLET PREPARATION

Types

The extrusion press requires a supply of round billets with a suitably prepared surface and of a diameter to

fit the container. These must be cut into the weight that will give the desired length of extrusion.

There are four possible sources of material: cast; continuously cast; rolled; forged. In assessing which of these to use it must be remembered that the overall reduction from ingot to extruded bar should be of a similar order applicable to other hot-working processes if similar physical characteristics are required in the final product.

Cast material

This would appear to be a cheap source of raw material, but unfortunately it suffers from very severe drawbacks. Its use is limited in some cases by the necessity of catering for adequate reductions to break down the as-cast structure, and this is accentuated by the fact that the pressure required to extrude cast material is higher than for rolled or forged stock extruded through the same die.

At Low Moor the billets for extrusion are $4\frac{1}{4}$ in., $5\frac{1}{8}$ in., and 6 in. dia. and 10–24 in. long. Round ingots cast by traditional methods are tapered and in the required diameters can only be cast in lengths suitable for the production of two short billets or one long one. On each ingot there is a top discard which reduces the yield obtained, although the head may be left on to form the extrusion discard, which would affect some improvement.

An ingot surface is rarely suitable for extrusion into a finished bar or section. It is therefore desirable to machine the ingots before extrusion, and this introduces further difficulties because of the short lengths and taper. Thus, machining tends to be excessive, resulting in heavy metal losses and tool wear.

Attempts have been made to overcome some of these difficulties by casting longer lengths in parallel-sided water-cooled moulds, but unfortunately these ingots frequently suffered from piping.

Continuously cast material

This is the most promising form of cast material for use in extrusion plants. It can be obtained in lengths that are suitable for mechanized turning operations. The length can also be adjusted to give exact multiples of the billet length required and so avoid wastage that occurs when conventionally cast material is used, and there is no loss due to discard. It has also been found that piping is virtually eliminated.

Austenitic stainless steel, continuously cast by Low Moor Alloy Steelworks, has been successfully extruded into simple shapes but so far has not been used for routine production. The surfaces of the cast billets are not suitable for extruding without machining, but the greatest trouble is the difficulty of casting a perfectly round bar; there is always some degree of ovality, which results in heavy machining losses.

Examination of extrusions produced from continuously cast rounds in austenitic steels showed that although the surfaces were satisfactory, the cast structure had been reproduced as a 'ghost' in the extruded bar. Extensive tests proved that the 'ghost' structure did not affect the mechanical properties, which were equal to those of the rolled product.

Typical mechanical results on 18–8 stainless steel extruded bars were as follows:

	A	B	C
Max. stress, tons/in²	41·80	40·0	46·8
Elongation, %	50	47	45
Izod, ft-lb	118	110	100
Brinell hardness	175	172	179

Rolled billet

This is probably the best form of extrusion stock. Billets can be obtained in long straight lengths rolled to a fairly close tolerance. In carbon and low-alloy steels this surface is sometimes good enough for extrusion after a descaling operation, but in most cases machining is necessary.

Forged billet

In alloy steels this appears to have some advantages over rolled billet. There is less centre looseness and better-surfaced extrusions are obtained, but a hammered surface is never satisfactory for extrusion and all billets must be turned. The turning losses are higher than those on rolled billets owing to the inability of forges to hold close tolerances on billets of the size and weight required for extrusion stock.

Structure

All steels must be fully killed and of a reasonable standard of microcleanness, as subcutaneous defects and inclusions tend to cause tearing during extrusion. Billets with slight pipe or centre looseness are sometimes acceptable for the production of hollow sections, as these are bored before extrusion, but such billets cannot be used for solid sections as they are liable to cause internal defects and a variation in size throughout the length of an extrusion.

A marked dendritic structure is not to be recommended as it will be reproduced as a 'ghost' structure in the extruded bars.

A duplex or eutectic structure, especially that with a continuous film around the grain boundaries, is best avoided as the bar may tear owing to hot-shortness. This is more serious than in the case of rolling or forging operations because of a rise of temperature during extrusion, which may take a steel from a safe hot-working temperature into a zone of hot-shortness, with the result that the back end of the extrusion may be torn. This tearing is also influenced by the extremely rapid reduction carried out in the extrusion press, which is a much more severe operation than that of rolling or forging and places a much greater strain on any parts of the billet that may be weak or brittle.

Analysis

Carbon and low-alloy steels can be extruded without the necessity of having closely controlled analyses, the only proviso being that the steels should be fully killed. High-alloy steels of the martensitic stainless types do not give any trouble due to variations in the composition of the steel.

Austenitic stainless steels, however, must have a very carefully controlled analysis, and a low ferrite content is essential if these steels are to give satisfactory extrusions. This has led to Low Moor Fine Steels having to use limited analyses within the British Standard Specifications for En58 and sometimes

having to work to special analysis, to minimize the ferrite content of the steel.

For example, satisfactory results can be obtained from analyses of the following types, but unfortunately these are outside the normal range for En58B and En58J respectively, although they are in line with the current US specifications for wrought materials.

18–8 titanium-stabilized

C	Mn	Si	Ni	Cr	Ti
0·08 max.	1·5–2·0	0·4–0·6	11–12	17–17·75	5×carbon

18–8–Mo

C	Mn	Si	Ni	Cr	Mo
0·08 max.	1·5–2·0	0·4–0·6	13–14	17–17·75	2·2–2·7

This would indicate the need for new British Standards to cover the process of steel extrusion and the steels used.

BILLET HEATING

Types

Various forms of heating can be used in the extrusion process, each having its own advantages and disadvantages. The most common are: gas; gas with atmosphere control; salt bath; natural gas; Balestra glass furnace; induction heating.

Originally the billet heating at Low Moor consisted of a gas-fired preheating furnace and a circular salt bath for bringing the billet to final temperature. For the reasons given below it was decided to install Loewy Magnethermic low-frequency induction heating coils in 1957, the first billets being heated in November of that year. At the time it was the only steel extrusion plant in Europe to be thus equipped on a production basis.

Before any decision can be taken as to the best form of heating for any particular plant, there are certain points that must be borne in mind. Firstly, the probable future order position must be considered, to enable some idea of the possible loading to be assessed. Secondly, it must be ascertained whether the plant is to concentrate on stainless steels, carbon and low-alloy steels, or tool steels, or a mixture of all three. The type of production will have rather a large part to play concerning the choice, because of the danger of scaling on the mild steels and decarburization on tool steels. When all the factors have been considered it is essential to see that the heating medium can cope satisfactorily with the maximum pushes per hour of the press.

All these problems were discussed at Low Moor during the latter half of 1956, when it was realized that the salt bath was a very wasteful and unsatisfactory form of heating for our purpose. Apart from high maintenance costs there was a great loss of heat to the rest of the building and a large salt loss carried over to the press. Ultimately it was decided that low-frequency induction heaters should be installed, because it was felt that during the development period of the extrusion process the load would inevitably be of an intermittent and varying character, and under these conditions gas and salt furnaces are not very economical units to run. Although the initial cost of induction heating was higher than for a gas furnace of similar capacity, taking the long-term view, the savings in running costs would, to some extent, offset this, since the heater can be switched off immediately the billet is ejected, no current being consumed in down-time.

The choice of induction heating was further influenced by the fact that a large proportion of the working load was for carbon, low-alloy, and tool steels. Faced with this position it was obvious that steps should be taken to minimize oxidation during heating.

Induction heating coils were considered to be the best means of obtaining scale-free billets (*a*) because the heating cycle is short compared with other forms of heating, so that scale formation is kept to a minimum, and (*b*) because heating can be carried out in an inert atmosphere.

Scaling

The effects of scale on tooling are already well known in all types of steel forging and rolling operations. It is sufficient to say that considerable die wear can result from a scaled billet, and container life is reduced by the cumulative effect. Scale, extruded through the die, will cause serious defects in the extruded bar, and it is therefore worth taking special precautions to overcome this.

Scale formation can be prevented by providing an inert atmosphere in the coil; in addition, by arranging for the heated billet to roll through a layer of glass powder immediately it emerges from the coil, the whole problem of oxidation is largely overcome.

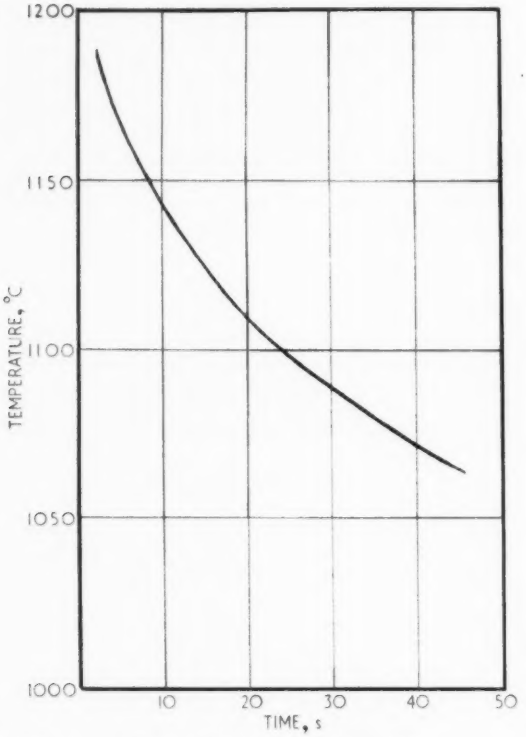
We have found that if any scale is allowed to form on the billets in the coils, the readings from the radiation pyrometer are affected. To overcome any danger of overheating due to inaccurate temperature indications, a kWh meter has been incorporated in the heating circuit. This meter can be set so that any number of kWh can be put into a billet; when the billet weight is known it is a fairly easy matter to determine the heating time required to bring it up to temperature.

Heating characteristics

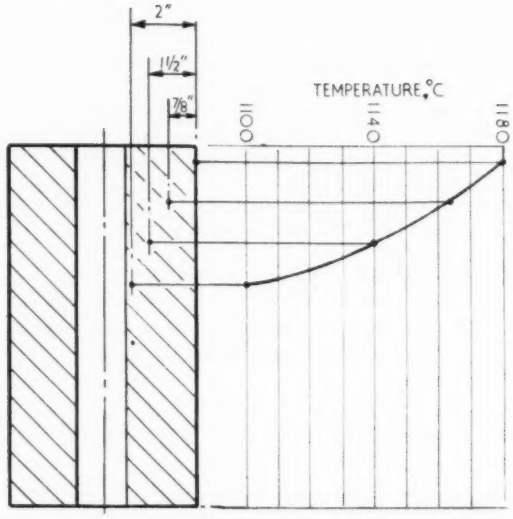
One of the lessons that has been learned is the necessity to transfer the hot billet from the coil to the container as quickly as possible. It frequently happens that a particular extrusion requires the press to be used at its maximum specific pressure, and in these circumstances any undue loss of heat by the billet, resulting from excessive handling time, will prevent satisfactory extrusion. In order that some idea may be formed of the loss of heat from a billet, various tests were carried out with the result shown in Fig.6.

Possibly no other aspect of steel extrusion has received as much attention as the homogeneous heating of the billets. When billets were heated in a salt bath they were considered to be thoroughly soaked and homogeneous after 20 min. Owing to the unavoidably excessive handling times from salt bath to press, temperature differences of the order of 100°C have been recorded, with the core hotter than the outside of the billet. This is an undesirable condition for the extrusion of steel, and the very opposite has been found to produce better results. For hollow sections and finned tubing particularly, a cooler bore is desirable.

To illustrate the type of temperature gradient desired for hollow sections a typical curve is shown in Fig.7. This relates to the heating in an induction coil of a hollow mild-steel billet, 24 in. long×6 in. dia., destined for the production of an eight-finned tube. Thermocouples were placed at equal intervals from



6 *Heat loss curve: 5⅛-in. dia. billet (stainless steel)*



7 *Temperature gradient in billet for hollow 8-finned tube*

the outside of the billet to the core, and the temperature, as indicated by the surface measurements, was raised to 1180°C as quickly as possible. The temperature gradient indicated by the curve is considered to be about ideal and experience has shown that if there is any cycling, however short, at the final temperature, the temperature gradient thus reduced invariably results in torn fins.

The reason for this would seem to be that, during extrusion, if the whole of the billet is at a uniform heat, the core flows at a faster rate than a corresponding point on the billet surface, even with simple shapes. In the case of extruding eight-finned tubes, the friction around the fin periphery is much greater than around the mandrel. Consequently there is a marked tendency for the fins to tear because the flow at the skin is being held back, relative to the bore, owing to the increased friction.

It is our theory that by arranging for the core to be relatively cold, extrusion of the centre portion of the billet around the mandrel is retarded relative to the skin, which allows the fins to be formed without danger of rupture.

In certain cases, when dealing with special austenitic stainless steels, some modification of the above technique has been found to be desirable. For instance, we can quote examples where extrusions of large cross-sectional area in 18–8–Nb and 18–8–Mo steels were required to be produced from billets of maximum length in the largest (6¼ in. dia.) container. The final temperature for extrusion for these steels was 1275°C but, as the sections were at the top limit capable of being dealt with by the press, necessitating the highest specific pressure available, it was necessary to ensure that the temperature gradient of the billet was not too great, otherwise the core might have been too cold to deform. This was achieved by cycling the billets at 1175°C before raising to the extrusion temperature. In this case a cycling temperature of 1175°C was chosen, not only to ensure a suitable temperature gradient within the billet before extrusion, but also to avoid the formation of any delta ferrite, which tends to be produced upon soaking at temperatures in excess of 1200°C, since duplex structure of austenite and delta-ferrite is known to be detrimental to hot-working. We have since standardized on this procedure for work of this type with satisfactory results.

No trouble has been experienced in the rapid induction heating of tool steels; 5⅛ in. dia. billets of 18%W high-speed, 6–5–2 high-speed, and 5%Cr–Mo tool steels have been heated to extrusion temperatures in 8 min. Only very obvious minor precautions have to be taken. The billets must be preheated to 150–200°C to avoid the initial shock and then it is preferable to cycle for a few seconds at about 600°C to equalize the gradient in the billet before taking it up to final temperature.

EXTRUSION

Lubrication

Workers in the field of steel extrusion using glass as a lubricant need more information on the behaviour of glass at high temperatures. The authors feel that more thought should be given to the subject of glass as applied to extrusion, with a view to improving the extruded product. In the extrusion process there are many variables and we do not consider that any one glass will suit all conditions. The subject of network formers and modifiers in the soda–lime–silica system has been rather neglected in day-to-day extrusion, but with the assistance of the glass technologists we are sure specifications will be introduced that will answer every requirement.

A definition of a true glass has been given as a liquid having 'virtually infinitely high viscosity, which in

heating shows no sharp transition to the fluid state'.[1] This definition fits the first requirement of any lubricant used for extrusion, that of having no sharp transition to the fluid state. Viscosity of the glass plays an important role in the process; just how important is difficult to say because the behaviour of glass at high temperatures under high specific pressure is not fully known.

The second property that has a decided effect on the use of any glass is its thermal conductivity. Hot extrusion of steel calls for a complete protection of liner, die, and holder during the extrusion stroke, even though this is designed to be completed in the shortest possible time, say, 3–4 s, and a requirement of the lubricant is that it shall insulate these parts from the hot billet. However, it is also very important that, in addition to insulating, the glass shall possess the property of being able to transmit enough heat to warm and soften successive layers.

Lubrication has to be considered in two separate stages; die lubrication and container lubrication.

Die lubrication

A glass pad is placed against the die for the lubrication of the extruded bar. As the billet passes through the die, the thickness of the glass pad diminishes as succeeding layers of glass are softened and carried through the die. As the extrusion is generally completed in under 4 s, a glass must be chosen that will react quickly in the manner required. At the same time, one must bear in mind the changing conditions during an extrusion. As there is an increase in temperature during extrusion the chosen glass must take care of this, without showing any major change in viscosity.

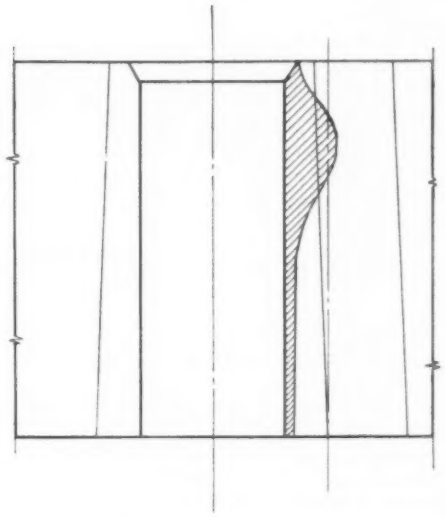
Our theory is that for a particular extrusion in a certain material, working at a given extrusion ratio, there will be an optimum glass viscosity that will give good results with a minimum of tool wear. This theory assumes that glass acts in a similar manner to that of the steel being extruded, in that there is an optimum speed and temperature at which it should be worked. Whenever these two parameters are exceeded the lubrication breaks down; the glass film, in other words, has not been able to stretch and move through the die and leaves dry patches on the extrusion, as a result of which the die overheats, causing a tendency to wash.

Container lubrication

Not least of the requirements of any glass chosen for its lubricating properties is its ability to 'wet' the billet thoroughly in order completely to eliminate oxidation and avoid excessive friction in the container during extrusion and probable defects in the extruded bar. It must also be one which will not harden when it comes in contact with the relatively cold container wall. If the chosen glass does not become fluid and cover the billet adequately, friction inside the container may reach such undue proportions as to make it impossible for the steel to be extruded. Such a billet is referred to as a 'sticker' and must be avoided at all costs, because of the severe cumulative effect on liner life and press foundations.

Tooling

From the outset, our policy has been to extrude the greatest possible length. As a direct consequence extrusion temperatures have tended to be increased until they have now reached 1275°C for the manipulation of some sections in 18–8–Nb steel.



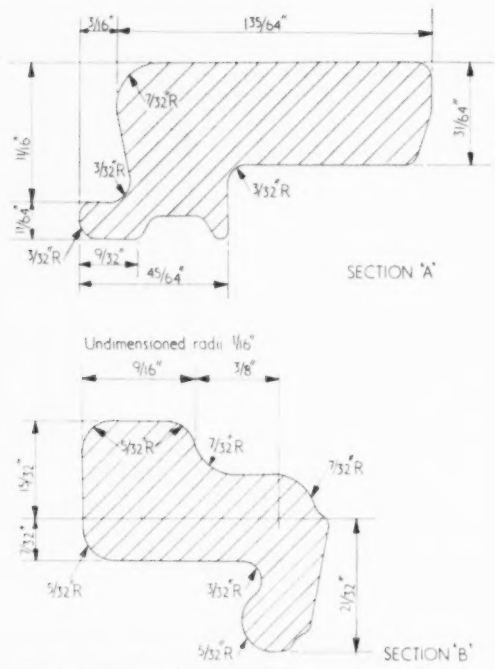
8 *Probable isothermal pattern in wall of liner*

To deal satisfactorily with extrusions in this temperature range at specific pressures of up to 52 tons/in², it is essential to have tooling of the necessary calibre. The materials used must possess sufficient hot strength and resistance to abrasion, lend themselves to machining, and also be amenable to fabrication by shrink fitting, as in the case of the liner.

Container

Normally containers for steel extrusion are built up as a three-component system, the inner shell of which is called the liner. The liner itself is perhaps one of the most critical parts of the extrusion tooling and opinions vary as to the most suitable type of material to use, as well as the best method for fitting. To provide the necessary strength and resistance to wear, it is usual to make the liner of the 9% tungsten-type steel heat-treated to a Brinell hardness of about 475. This is the type preferred at Low Moor Fine Steels. A liner of the cheaper 5%Cr type may be suitable for extrusion of thick-walled stainless tube with billet temperatures in the region of 1130–1200°C, but would not be considered suitable for medium or high production rates in the working range 1200–1275°C.

The type of wear which takes place has been discussed by Rodgers.[2] who showed the temperature gradient along the liner (Fig.8). Because of the time lapse before the discard is pushed out of the container, the surrounding portion of the liner becomes much hotter than the main body. Any comparatively cold discards, or stickers in particular, cause severe abrasion at this point and frequent inspections are made of the liner condition. In order that the container does not become too hot it is necessary to turn off the preheating device round the outside of the container, especially when extruding billets over 1200°C.



9 *Sections made on 4 5/16-in. container*

Pressing stem

Next in importance is the pressing stem which, like the liner, has to perform an arduous duty, but fortunately not in association with high temperature. The steel used is of the 2%Ni–2%Cr–½%Mo type having a Brinell hardness of 460 minimum. By use of a pressure disc placed on the end of the stem, direct contact with the billet is avoided. Precautions must be taken, however, to ensure that the interface between the stem and the pressure disc is not impaired by successive mushrooming and chipping of the stem. Periodically the stems are set up in a centre lathe and the front faces trued up with the central axis. In the case of hollow extrusions this has been found to improve the concentricity of the bore.

Pressure disc

There are two steels in common use, the 9%W and the 5%Cr–Mo types, the latter being the more favoured because of its ability to be water-cooled without cracking. As with the stem, the pressure discs are periodically trued up in the lathe to maintain a strict alignment on the stem face. By so doing, undesirable stresses are reduced to a minimum, the ram force is directed in one plane, and concentricity of hollow extrusions is improved.

Dies

One of the problems associated with the extrusion process is providing a die material that will enable an economical number of extrusions to be obtained. Various types of material have been tried, the one giving most consistent results being the 9%W type. Initially the dies were heat-treated to give 44 Rockwell C, but now the more favoured hardness is 49–51 Rockwell C. In the search for improved materials we have recently developed a 4¼%W–Cr–Co–V–No steel which is giving encouraging results at a hardness of 56 Rockwell C. At the present time, both materials are being used for the longer production runs.

The extrusion die designers have a vast range of hot die steels from which to choose, but the field can be narrowed by reviewing some of the requirements that govern any choice.

Cost The initial cost of a die blank does not appear to be large when compared with other items in the process. However, when large numbers are manufactured every year, a saving of £1 per die can considerably affect the running expenses of the tool room. The factor most influencing the die material to be used is the size of the order. Quite often it is possible to use a cheaper die steel of the 5%Cr–Mo type, particularly where the section is not of a difficult nature.

Machinability The material chosen should preferably be available in the condition which permits easy machining by conventional means. A certain amount of work is being done with Nimonic dies, but great difficulties have been encountered in machining the required profiles. It is possible, of course, to use spark erosion for forming such die blanks, but the economics of this method have to be carefully assessed; the cost of the necessary electrodes for some of the sections extruded would be more than the cost of several dies made by normal methods.

Hardenability A steel must be chosen that will give the necessary degree of hardness and retain sufficient toughness to withstand the stresses during extrusion.

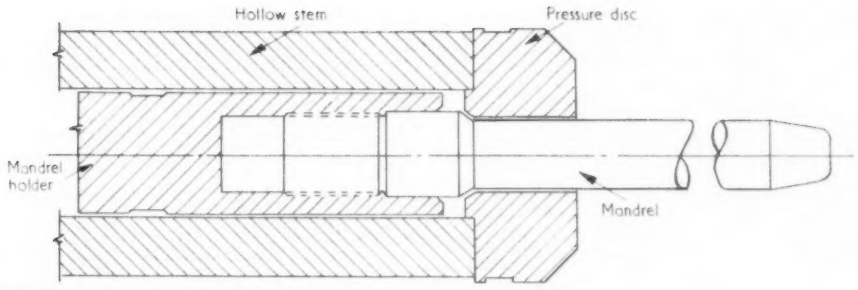
Heat checking Any material that is considered for dies must be able to resist cracking due to thermal fatigue, as all dies are subject to cyclic heating and cooling. When only a few are in use it may be necessary to air-blast cool them so that they can be used at frequent intervals.

Hot strength and wear resistance It is essential that all die materials should have adequate hot strength so that no wash occurs during extrusion.

Typical analyses of die steels used

	C	Si	Cr	Mo	W	Va	Co
9%W	0·30	0·30	3·25	...	9·0	0·25	...
5%Cr–Mo–W	0·35	1·00	5·0	1·65	1·55	0·25	...
4¼%W–Cr–Co–V	0·40	...	4·25	0·40	4·25	2·25	4·25

Die wear is the greatest factor influencing tolerances on the finished product, especially when 90% or more of production is sold in the 'as-extruded' condition. The desirability of having a die material that can do for steel extrusion what tungsten carbides have done for the cold-drawing industry can be appreciated. Unfortunately there seems to be some reluctance on the part of the tungsten carbide manufacturers to undertake work in the field, especially for the difficult sections for which the need is more desperate. For instance, on the two sections shown in Fig.9, only by judicious welding repairs was it possible to obtain ten extrusions from die A and eight extrusions from die B. These figures are not satisfactory and it is desirable that they be improved upon by the use of a die



10 *Original mandrel, holder, and hollow stem*

material which will withstand wash better at the sharp re-entrant portions.

As a direct contrast, the eight-finned tube die gave better results, many of the dies in the batch executing over 100 extrusions.

The sections in Fig.9 were made on the 4 $\frac{5}{16}$ in. container, where the specific pressure is 57 tons/in². On the other hand, the eight-finned tube was produced on the 6$\frac{1}{4}$ in. container, where the specific pressure is 36 tons/in². Comparing these figures with the average number of extrusions per die on each container for all orders taken over a 12-month period, it was found that on the smaller container the average number was 19 per die, while the 6$\frac{1}{4}$ in. container had an average of 60 per die. The sections extruded from the 4 $\frac{5}{16}$ in. container are usually very small with high extrusion ratios, and it is known that dies for this type of section suffer unduly from wash and subsequent loss of dimensions, due mainly to the higher specific pressure. Although this is considered to be the main reason, complexity of the section may also have some bearing.

Die production Two main lines have been pursued in order to minimize what could become an intolerable position with regard to die cost. These are the use of shell-moulded dies and repairs to dies by welding.

In the case of shell-moulded dies, it is not economical in the ordinary way to prepare patterns and cast dies for the small-quantity jobs where only two or three dies are required, and it is not always feasible to assess the possibility of repeat orders for the same section; if it were so the chance would be taken and extra dies cast. Moreover, the customer often requires some modifications to the prototype section. For these reasons, therefore, it has been considered desirable that orders calling for small numbers of dies should be tooled up from forged blanks. For large orders requiring considerable numbers of dies the use of shell-moulded dies in standard 9%W steel is fully justified, and our experience has shown that these dies are equal in performance to those prepared from forged blanks.

The practice of welding dies has grown and is now firmly established in most extrusion plants since this can considerably prolong the useful life of a die.

Mandrels Quite a large proportion of current production is in the form of hollow sections, requiring the use of a mandrel.

A typical assembly of mandrel, mandrel holder, and hollow stem is shown in Fig.10, this being the original design supplied with the press. This design of mandrel proved to be expensive because of the various diameters required and because for each mandrel size a series of pressure discs was required. To simplify the process a mandrel adaptor was made which screwed into the mandrel holder. This in turn was bored out and threaded to take any size of mandrel required.

For the normal type of hollow extrusion, where no particular difficulties appear, the mandrel is made from 5%Cr–Mo–W steel, but below 1 in. dia. it has been found desirable to use a higher quality steel such as 6–5–2 high-speed steel or 9%W steel, because of the higher working temperature.

One of the major reasons for choosing 5%Cr–Mo–W steel was the necessity for cooling the mandrel by water spray between extrusions. The temperature may be 400–500°C and it is necessary to cool down to 100–200°C. Modern presses are now being fitted with automatic cooling devices for the mandrel, the water being passed up a bored hole in the centre.

The higher tungsten qualities are not suitable for water-cooling after extrusion and so air-cooling has to be adopted, which results in inconvenient delays.

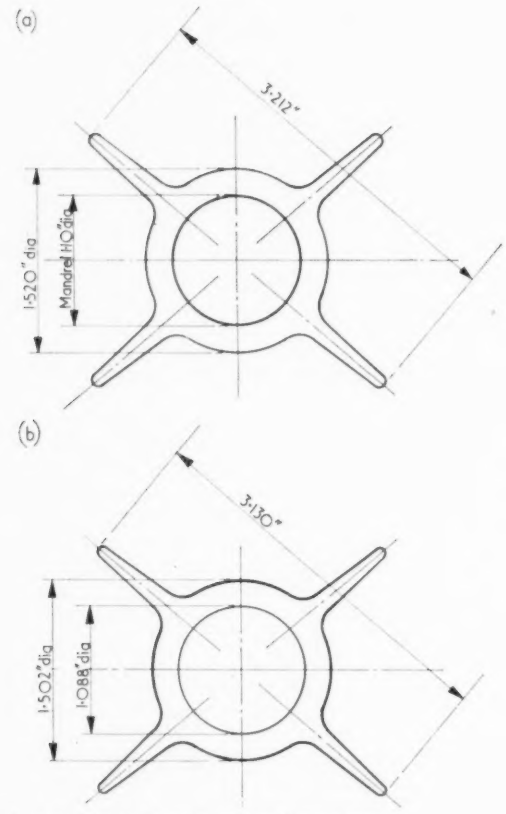
During the course of producing the different types of mandrels, various heat-treatments have been considered and tried. The most satisfactory results have been obtained when the steel is heat-treated to a Rockwell hardness of about 49–51C. The useful life of a mandrel can usually be gauged from a consideration of its task, taking into account the diameter of the mandrel, its length, the material being extruded, and the temperature of the billet.

As an example of how various factors can affect mandrel performance, two cases will be cited.

The first example relates to extruded hollow hexagon bar in 25–20Cr–Ni steel having dimensions of 1 in. across flats and a wall thickness of $\frac{5}{32}$ in. The billet was 11 in. long and was bored out to $\frac{13}{16}$ in. This gave a product length of 20 ft and was extruded at a temperature of 1250°C. The material chosen for the mandrel was 5%Cr–Mo–V, and after extrusion severe necking was observed at the back end of the mandrel. Even with adequate lubrication there was not enough protection of the mandrel at this extrusion ratio (29:1) and pressure (about 36 tons/in²).

Further mandrels were prepared in 9%W steel heat-treated to a Rockwell hardness of 49–51C, and the initial extrusions had no adverse effect on the mandrel surface.

In both cases the extrusion speed was high to avoid lengthy contact between the hot billet and the



11 (a) *Die* (b) *Extruded section dimensions*

mandrel, and in the case of the 9%W mandrel, air-blast cooling was used between extrusions which appeared satisfactory on this rather small size.

The second example concerned the 5%Cr–Mo–W mandrel for the mild-steel eight-finned tube, where the duty was not so severe and the specific pressure was about 25 tons/in^2. In this case the extrusion ratio was only 12:1 and the extrusion temperature 1180–1200°C. The original billet length was 11 in. bored out for a mandrel diameter of 1·6 in.

When it became obvious that a mandrel was producing at least 100 extrusions without showing any signs of wear, it was decided to double the billet length. Again very high performances have been obtained, although it is expected that some mandrels will require welding before completing 100 extrusions in the double length.

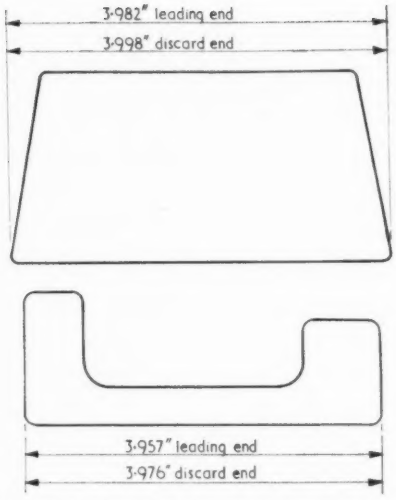
It is our opinion that further studies into electroplated chromium and flame-plated carbide deposits will result in longer mandrel life, and we intend to give extended trials to these at Low Moor.

DIMENSIONAL STABILITY

Factors most affecting the dimensions of the extruded product, will now be considered.

Extrusion temperature

This is determined by the plasticity required to push the steel through the die. Having established the



12 *Thickness of glass film decreasing from front to back of extrusion*

required temperature, it is possible to determine the contraction that will take place, and in the case of mild and carbon steel, allowance must also be made for a small scaling loss.

Shape of section

Those sections that have very thin projections away from the main mass require special treatment regarding contraction allowances, and the template shape used for die making and checking of the die during extrusion usually bears no proportionate similarity to the finished contour.

In most cases of this type, greater contraction allowances must be assumed because differences in shrinkage are a function of the complexity of the section and are influenced by the ratio Principal Mass/Mass of projection. An example of this type is indicated in Fig.11 where the die aperture is shown, together with the dimensions of the finished section. With simple shapes it is possible to maintain a general tolerance of 0·030 in., but in the case of finned sections a tolerance of ±0·040 in. would be more appropriate.

Type of glass

One of the main considerations in the extrusion of steel is the type of glass to be used, both its properties and physical conditions being important. Glass lubrication is, of course, the crux of the patented process and has been discussed in a paper by Haffner and Séjournet.[3]

Material

Apart from the fairly obvious point made earlier regarding billet temperature affecting the contraction of a section, the various types of steel being extruded affect die sizes in other ways. As the resistance to deformation increases there is a rise in specific pressure at the beginning of the extrusion, which is usually an indication that the thickness of glass will be greater on

the first foot or so of bar, thus reducing dimensions locally.

Another important feature relating to the type of steel is that as resistance to deformation increases and it becomes harder to work, it follows that there is a greater overall die wear, which considerably upsets the desired contours.

Extrusion speed

It is desirable to extrude at as high an extrusion speed as possible; this has been found to produce more consistent sections. Results on sections extruded in 36-ft lengths at speeds in excess of 15 ft/s indicated that the overall dimensions did not vary more than 0·015 in. from leading end to discard end of the bars. However, when low extrusion speeds are encountered, as often happens when the press is being taxed to its limit, there can be quite a large variation in dimensions. It has been noted in such cases that the thickness of the glass film decreases uniformly from the front part of the extrusion to the discard (Fig.12).

Extrusion ratio

The main effect of extrusion ratio is to dictate the specific pressure required for any particular extrusion. High ratios, requiring high specific pressure, will naturally occasion greater die wear than medium or low ratios. If it is found that the wear on any die is too critical, the job can sometimes be extruded satisfactorily on a smaller container.

Another feature of high extrusion ratios as affecting the product dimensions is that the thickness of glass along the extruded bar is generally greater than on a bar extruded at a lower ratio, but the difference is usually insignificant and can be accommodated in the general tolerance.

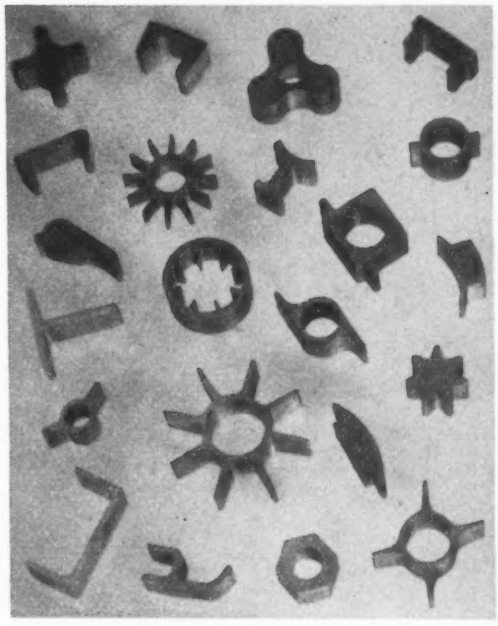
Die and die holder

It is outside the scope of this paper to give any details of die making, but it is stressed that accuracy, not only of the die itself but also of the assembly in the holder, is of paramount importance.

Die temperature

Dies are initially preheated to about 200°C. In service they can reach local temperatures in excess of 600°C and they are air-cooled to about 200°C before re-using.

It is important, if close tolerances are the first objective, to limit the temperatures attained by the die in service. This is influenced by other factors, not least of which is the number of dies it has been economically possible to make for any one section. The number of dies available determines the interval of time between each full cycle. If there are few dies the cooling time is short and overheating is the usual result, particularly of re-entrant features of the die profile. It is noted that owing to the outer portions of the die being comparatively cold, almost all the expansion takes place towards the centre and the aperture thus becomes smaller than is desired. This effect taken alone is not necessarily objectionable, but can become undesirable in conjunction with a higher billet temperature.



13 *Typical extruded shapes*

One of the most serious effects of overheating of the die is the possibility of 'wash' on re-entrant features of the aperture. As this occurs during an extrusion there is nothing that can be done until the die is taken out for cleaning. It is a simple matter to grind and file to shape again, but eventually, with the increase in aperture, the die will need correcting by welding.

CONCLUSIONS AND FUTURE TRENDS

There are many mistaken concepts regarding the limitations and versatility of steel extrusion. It is often asked whether the extrusion press can eventually supersede the rolling mill. The answer is that it already shows many advantages and doubtless the time is not far distant when it will compete fairly successfully with a jobbing mill.

For the present, however, it must be admitted that it is not suited economically for the production of standard shapes that can be readily rolled, especially in mild steel and low-alloy steels; but a different picture is presented if there is a requirement for a non-standard shape. This is especially true where the quantity is small, as extrusion die costs are very low relative to roll costs.

At the present time, therefore, the steel extrusion plant can be said to be best suited to the production of:

(i) non-standard sections, especially relatively small quantities
(ii) sections that it is impossible to roll by reason of their shape, such as finned tubing
(iii) sections in material difficult or impossible to roll or forge, such as certain nickel-base alloys, which can be extruded to produce reasonable yields but which break up in rolling or forging
(iv) sections (particularly in stainless steel or other highly alloyed materials) where a quick delivery can offset a somewhat higher cost.

There is no doubt that the ever-increasing trend of industry to use relatively expensive stainless steel components will considerably help the development of the extrusion process. Of these there will be a good proportion of weight-saving hollow sections with which only the extrusion plant can cope.

Meanwhile, it is the task of the extruder to show industrial designers the new shapes that can now be made available, shapes which hitherto have been supplied only in light alloy materials and which can be fittingly described as a 'draughtsman's dream' in steel.

One of the important contributions already made to industry has been the ability to offer steel sections that require little or no machining. This is one of the major assets which has proved so useful in the aircraft industry, where the use of extruded support ring sections has become a firmly established practice. Some typical examples of extruded shapes are shown in Fig.13, a good proportion illustrating how boring losses can be saved by the widespread use of hollow sections.

Future consideration must be given to increasing the use of cast material and, in this field, continuously cast round billets appear to show the greatest promise. It is very convenient that the authors have ready access to a continuous-casting plant at our associate company, Low Moor Alloy Steelworks Ltd, and it is hoped that we may be allowed to publish data on this subject in due course. The use of continuously cast billet will entail more research into lubrication, and higher extrusion ratios will also be desirable, not only to effect the necessary structural breakdown but also because they exert a beneficial influence on surface finish. Consequently the press designer will be called upon for larger presses with high specific pressures.

The modern press must at the same time shorten the extrusion cycle so that rates of up to 80–100 extrusions per hour can be obtained. It is only at such rates, for little increase in capital cost, that the extrusion press can hope to compare favourably with rolling costs. One possible future trend which suggests itself is the use of very large modern presses (say 20000 tons) to supersede cogging mills in the production of extruded billets direct from large ingots.

No discussion of this nature would be complete without reference to product yields and conversion costs. One of the immediate aims is the reduction of costs, in order that more sections can be brought within the scope of the process. This could be accomplished to some extent by an increase in tolerances but it is not a desirable solution; the very opposite has in fact been the policy of Low Moor Fine Steels, where we have set out to reduce the tolerances generally accepted for the process.

It is naturally the desire at all times to use the longest billet acceptable to the press and extrude the greatest possible length, which cuts down the number of discards and automatically raises the yield. It is also important to see that the discard is kept to a minimum.

On looking at the process carefully it would seem for the moment that the greatest opportunities of improving the yield exist in the preparation of raw material rather than elsewhere.

It is hoped this paper shows that the extrusion process can now be accepted as another means of fabricating steel on a commercial scale and, for this, we are indebted in the main to the Ugine-Séjournet glass lubrication technique.

We feel that the time has now arrived when official action should be taken to devise new or modified material specifications for the steel extrusion industry, as we are often working at a disadvantage in having to meet specifications that have been designed primarily for conventional methods of hot working. We can say with confidence that enough is now known about the process to lay down the manufacturing limits required, and it is hoped that the British Standards Institution may consider these proposals at an early date. In the meantime it is necessary to work for greater improvements in techniques and at the same time widen the fields of application by systematic lowering of production costs.

ACKNOWLEDGMENTS

The authors are indebted to the licensers of the process Comptoir Industriel d'Etirage et Profilage de Métaux, for permission to publish this paper, and to the directors of Low Moor Fine Steels Ltd who have given permission for its preparation and publication. They also wish to acknowledge the help they have received from colleagues in the preparation of photographs, drawings, etc. particularly Mr J. Richardson and Mr G. Hargreaves.

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Embrittlement of a 12%Cr–4%Ni steel

G. T. Brown and R. T. Allsop

SYNOPSIS

The extent to which a complex 12%Cr–4%Ni steel can be embrittled by heat-treatment has been examined. Heating in the temperature range 250–550°C produces a considerable increase in hardness and loss of room temperature impact strength. The magnitude of the changes produced by heating in the above temperature range is markedly influenced by the prior heat treatment of the steel. In particular, heating around 680°C before applying a lower temperature treatment delays considerably the onset of embrittlement. Impact transition curves and hardness have been studied in detail to determine the cause of the embrittlement. It is concluded that embrittlement arises largely as a result of a precipitation process although the possibility of some degree of temper embrittlement occurring cannot be excluded. Electrolytic extraction has been used to study the precipitating phases and it is found that in addition to niobium carbide a new phase, designated 'S' phase, is present. The composition of the phase approximates to M_3Si where M is largely nickel. The results obtained show that embrittlement after short periods in the range 250–600°C is due to the precipitation of 'S' phase rather than NbC. After long ageing periods the development of sigma phase maintains the embrittlement produced by short ageing times. 1719

INTRODUCTION

DURING THE COURSE of a general study of a steel of the 12%Cr–4%Ni type it was noted that heating in the temperature range 250–550°C could give rise to a severe reduction in room temperature impact strength and an increase in hardness. The purpose of the present paper is first to describe the characteristics of the embrittlement observed in the commercially produced steel, second to study the precipitation hardening effects attributable to a new Ni–Si compound (designated 'S' phase), and third to establish the composition of 'S' phase.

EXPERIMENTAL PROCEDURE

Steels used

The compositions of the steels used in the investigation are shown in Table I. Steels A and B were commercially produced to the same specification and were regarded as being interchangeable. Steel C was prepared in the laboratory to study the effect of reducing the silicon content to a low value. High-purity materials were used to produce cast C and melting was under vacuum; this necessitated the preparation of a similar cast D, which contained silicon and was used for 'control' purposes.

Impact testing

The impact strengths were determined using beam test-pieces of size 60 mm×10 mm×7 mm with a standard Izod notch (as described in BS131) cut in the 7 mm face. (The bar size available made it necessary to adopt this sub-standard test-piece.) Machining and notching was performed before heat-treatment to ensure full stress-relief, oxidation being only very slight in this type of material.

Hardness

All hardness measurements were obtained using a Vickers hardness testing machine with standard diamond indentor and 20 kg load.

Dilatometry

The ferrite–austenite transformations on heating and cooling were investigated by means of a dial gauge dilatometer. Heating was at the rate of 8°C/min in the critical region and cooling was in still air.

Retained austenite measurements

Since it was known that austenite was liable to be retained at room temperature extensive determinations were performed. An X-ray spectrometric technique similar to that described by Averbach and Cohen[1] was used. Cobalt Kα radiation was diffracted from solid samples which had been metallographically polished, etched, and lightly re-polished using 0–2μ diamond abrasive.

Electrolytic extraction

During the course of the investigation it was necessary to identify the various phases and precipitates which developed during heat-treatment. The phases were extracted electrolytically in a 10% aqueous hydrochloric acid bath. The extracted residues were then analysed chemically and identified by X-ray powder diffraction using a 19 cm camera.

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TABLE I Composition of steels

Cast	Element, %									
	C	Si	S	P	Mn	Ni	Cr	Mo	Nb	Al
A	0·055	2·50	0·009	0·015	3·00	4·21	12·01	0·04	0·63	0·035
B	0·050	2·72	0·008	0·014	3·20	4·36	12·61	0·015	0·61	0·05
C	0·014	0·40			2·60	4·07	10·80		0·65	
D	0·010	2·71			2·54	4·02	11·17		0·53	

RESULTS, COMMERCIAL STEEL

Embrittlement characteristics of commercial steel

To investigate the embrittlement which occurred in the commercially produced material three series of experiments were conducted, hardness and impact strength measurements being made. The experiments were designed to study the effect of:

(i) variation in initial heating temperature, starting with the as-received (hot-rolled) condition
(ii) variation in subsequent ageing temperature
(iii) increasing time at ageing temperature.

In the experiments on ageing time two initial heat-treatment temperatures were selected, 680° and 800°C. A temperature of 680°C appeared to be significant with regard to its ability to prevent embrittlement at short times of subsequent heating, while 800°C was a temperature which facilitated the study of 'S' phase embrittlement tendencies by reducing effects due to niobium carbide and retained austenite.

Transformation points

The ferrite–austenite transformation occurred, on heating, at about 590°C and was complete in the region of 700°C. On cooling from 850°C the martensitic expansion took place at 160°C and at successively lower temperatures when the austenitizing temperature was reduced. Cooling from 625°C resulted in the M_s point being depressed to only a few degrees above room temperature. The dilatation curves indicated that austenitizing in the range 600–680°C caused a considerable loss in specimen length.

Effect of initial heating

Room temperature impact and hardness values were determined after reheating specimens in the as-received (hot-rolled) condition for 1 h. The results are shown in Fig.1.

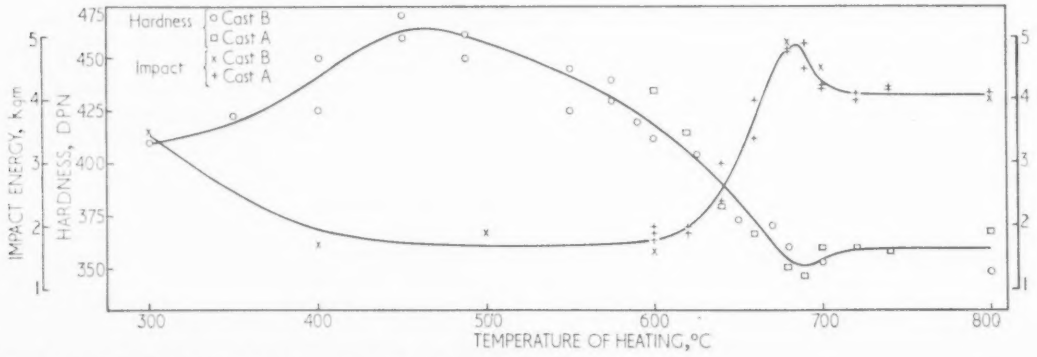
Effect of subsequent heating

Batches of specimens were first treated for 1 h at temperatures in the range 600–800°C. Subsequently, test pieces from each batch were reheated to temperatures in the range 250–550°C; room temperature impact and hardness values were then plotted against initial heating temperature for each condition of subsequent heating. Figure 2 shows the results using reheating treatments of 1 h at 550°C and 5 h at 450°C. Similar curves were obtained with treatments of 90 h at 350°C and 250 h at 300°C. Comparison of Fig.2 with Fig.1 shows that in the range 600–680°C ageing at 450° and 550°C does not significantly affect the manner in which impact strength and hardness vary with initial heating temperature; above 680°C significant changes are apparent.

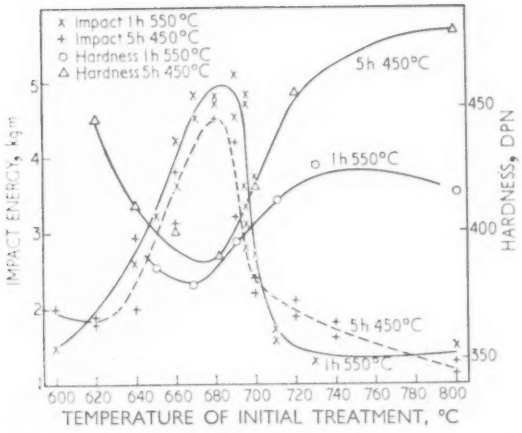
Effect of heating time

The effect of prolonged heating (ageing) on room temperature impact strength, hardness, and the shape of the transition curves was investigated. An initial treatment at 800°C was adopted. Figure 3 shows the effect of ageing at 300°, 450°, and 550°C on hardness and Fig.4 on room temperature impact properties. The rapidity of the fall in impact and rise in hardness on ageing at 450°C is notable. A certain amount of over-ageing was apparent on heating at 550°C but there was no rise in impact strength to correspond with this change.

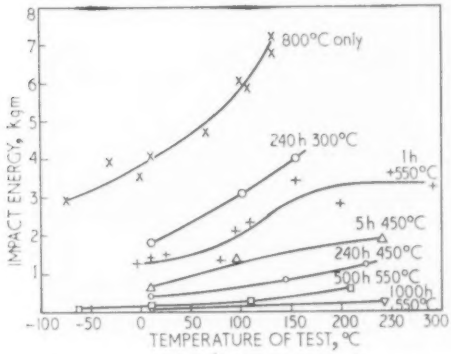
The impact transition curve for the 800°C treated condition is shown in Fig.5 which also shows the form of the curve for several reheating treatments. The shape of the curve after 1 h at 550°C is interesting in that it indicates that the whole curve suffers a modification rather than merely a movement in transition. Long times of ageing appear to eliminate a transition zone over the temperature range examined. The



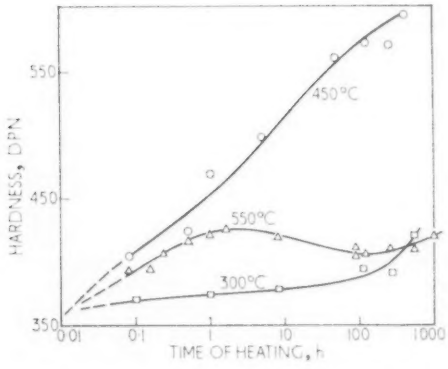
1 *Casts A and B, effect of single heat-treatment, all tests at room temperature*



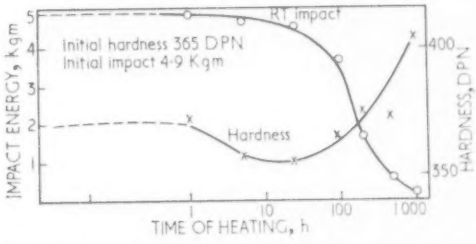
2 *Cast A, hardness and impact strength as a function of initial treatment after giving subsequent treatments of 1 h at 550°C and 5 h at 450°C*



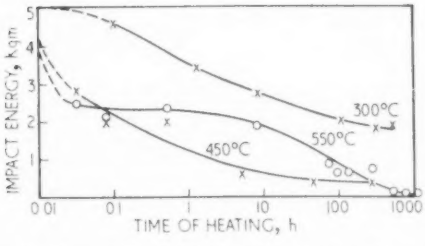
5 *Cast B, movement of transition curve after reheating for various times and temperatures, specimens initially treated at 800°C*



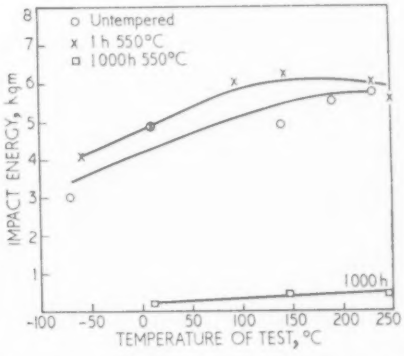
3 *Cast B, effects of heating time on hardness, specimens initially treated at 800°C and subsequently aged at temperatures indicated*



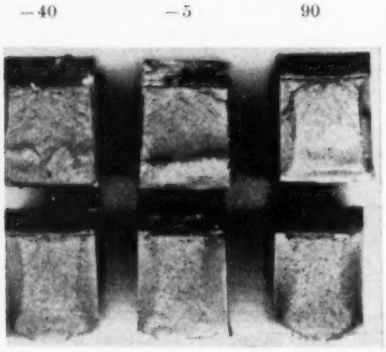
6 *Cast B, effect of heating time at 550°C, initial treatment at 680°C*



4 *Cast B, effect of heating time on impact strength, specimens initially treated at 800°C and subsequently at temperature indicated*



7 *Cast B, movement of transition curve with time of holding at 550°C, initial treatment at 680°C*



8 *Specimens fractured at temperatures shown (°C), treated initially at 800°C and subsequently at 550°C for 1 h*

maximum test temperature employed was limited to 300°C because of the tendency for the material to age fairly rapidly above this temperature.

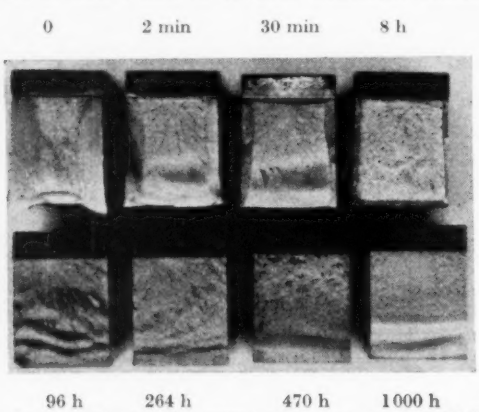
Considerably different behaviour on reheating was exhibited when the initial treatment was at 680°C. Ageing at 550°C produced little change in impact and hardness up to 10 h of heating; thereafter impact strength fell and hardness rose. Figure 6 shows these results. The transition curves were also somewhat different. Figure 7 illustrates the effect of ageing at 550°C; after 1 h a slight rise in the curve is suggested. At 1000 h the curve is once again reduced to a low level of impact strength.

Fracture

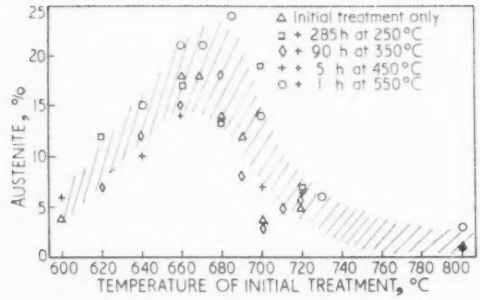
The impact test-piece fractures revealed the grain size to be exceptionally fine; there was no clear indication of cleavage facets even in specimens fractured at low temperatures. The degree of deformation was consistent with the change in impact strength. Figure 8 shows the appearance of specimen fractures with change in test temperature and Fig.9 the effect of increase in ageing time at 550°C on test-pieces fractured at room temperature.

Retained austenite

The impact test specimens used to investigate the effect of initial and subsequent treatment combinations were examined for retained austenite content. Figure 10 shows a composite graph of the results. The maximum amount of austenite was present in specimens heated in the range 660–680°C. Subsequent tempering appeared to have little effect on the austenite peak but scatter of results may have hidden significant changes in this respect. To investigate this particular aspect the specimens used to plot Fig.6, i.e. 680°C initial treatment followed by ageing at 550°C, were examined for austenite content. Figure 11 shows the results, the austenite content being significantly reduced only after 10 h of tempering at 550°C.



9 *Specimens fractured at room temperature, treated initially at 800°C and subsequently at 550°C for times shown*



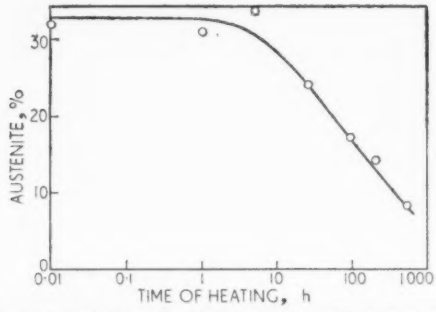
10 *Cast A, residual austenite as a function of initial and subsequent treatment*

Microstructure

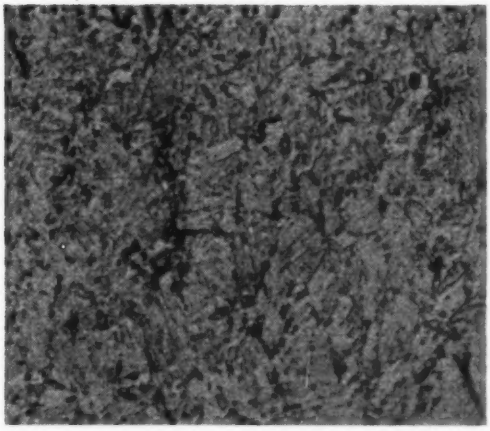
Specimens for metallographical examination were cut from the relevant impact test-pieces. In all specimens examined a minor quantity of elongated delta-ferrite was noted. Also present were angular niobium carbide particles occasionally occurring as elongated colonies.

The grain size of the steel was very fine in all cases. A specimen which had been treated at 600°C indicated grain boundaries which appeared to contain a precipitate although this detail was irresolvable with the equipment available. Figure 12 shows the structure of this specimen. As the initial heating temperature was increased the definition of the grain boundaries reduced and was almost absent with a 700°C heating.

The structure after heating at 800°C is shown in Fig.13*a*. On giving subsequent treatment at 550°C no difference was apparent in the specimens heated for short times. After 96 h of heating the structure became more difficult to resolve but there was some suggestion of a fine globular phase forming. After long times of heating a definite grain boundary phase was detected. Figure 13*b* shows its appearance at 264 h. This was



11 *Cast B, variation of austenite content with time at 550°C, initial treatment at 680°C*



12 *Structure as cooled from 600°C, etched in Vilella's reagent* ×1000

subsequently identified, by X-ray powder diffraction, as sigma phase. A similar development of sigma phase was apparent in the case of specimens initially treated at 680°C and aged at 550°C for long periods. Specimens aged at 450°C did not appear to develop a grain boundary characteristic.

Extracted residues

Specimens given initial treatments for 1 h in the range 680–1050°C yielded residues consisting wholly of niobium carbide.

The effect of ageing treatments was studied in some detail using an 800°C initial treatment; only niobium carbide could be extracted from specimens aged at 450°C but after 50 h at 550°C a second X-ray diffraction pattern was present. This grew in intensity with ageing time until a sigma phase pattern also appeared. The sigma pattern was strong at 264 h and increased in intensity, appearing to reach a maximum in the region of 1000 h. Figure 14 shows the appearance of some of the diffraction patterns studied and illustrates these changes. The phase which appeared at 50 h ageing time gave an X-ray diffraction pattern which was not listed in the ASTM index and so it was arbitrarily designated 'S' phase. Figure 14*b* shows the diffraction pattern of 'S' and niobium carbide extracted from a specimen aged for 96 h at 550°C.

Synthesis of 'S' phase

Sufficient of the extracted residue containing only 'S' phase and niobium carbide was prepared to enable microchemical analysis to be performed. Using the results from this as a basis several casts of material were prepared, variations in composition being made until metallographical examination and X-ray powder diffraction revealed a structure of very nearly pure 'S'. Table II shows the composition of this cast and Table III shows the X-ray diffraction interplanar spacings. The structure of 'S' appeared to be face-centred-cubic with parameter a=11·150 Å. Figure 14*f* shows the powder diffraction pattern from which the 'd' spacings were measured.

From Table II it can be seen that 'S' phase approximates to a formula of M_3Si where M is largely nickel.

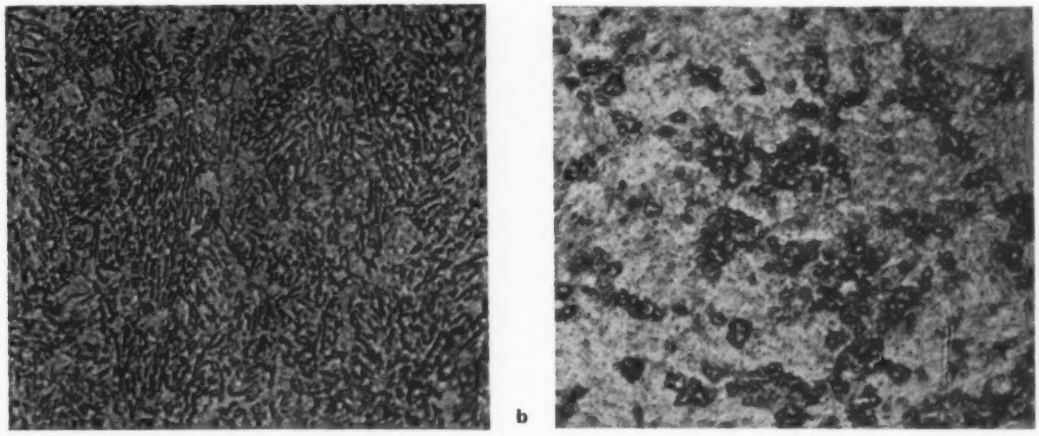
REVIEW OF RESULTS

In the introduction it was mentioned that a precipitation process was responsible for the embrittlement found. It is pertinent to consider at this point how the experimental results on the commercially produced steels lead to this conclusion.

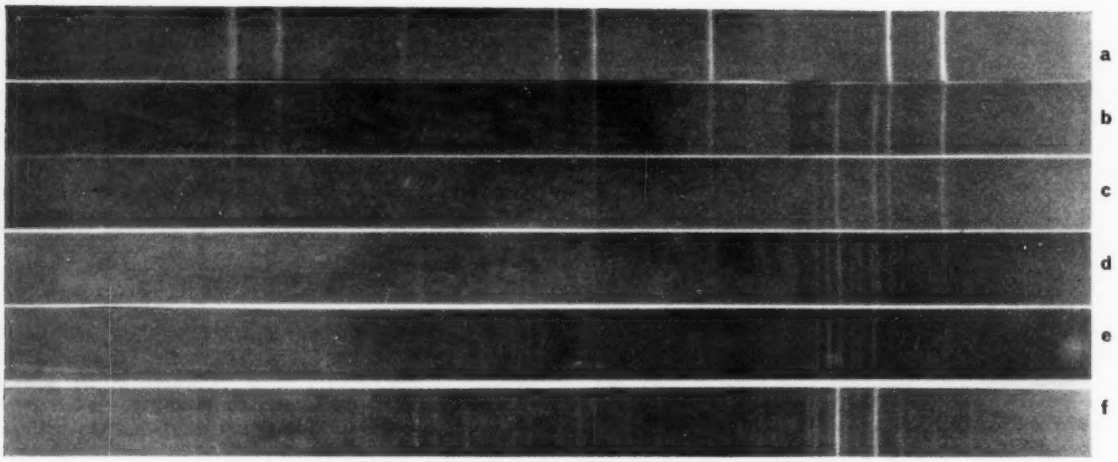
There are, essentially, four types of embrittlement effects which are applicable to this class of steel:

(i) temper embrittlement
(ii) '475' embrittlement
(iii) sigma phase formation
(iv) precipitation hardening.

The principle feature of temper embrittlement is that reheating in the critical region causes the impact transition curve to be displaced to a higher temperature while hardness and tensile strength are little affected.[2] Reference to Fig.5 indicates that in the present case the embrittlement is manifest as a complete modification of the transition curve which may incorporate a displacement to a higher temperature. Moreover, Figs.3 and 4 show that there is a notable



13 (a) *Structure as cooled from 800°C* (b) *Reheated to 550°C for 264 h. Sigma phase formed at boundaries, appears darker. Both etched in Vilella's reagent* ×1000



14 *Powder diffraction patterns* (a) *Initial treatment at 800°C* NbC *lines*; (b) *Subsequently given 96 h at 550°C* NbC *and* 'S' (c) *264 h at 550°C* NbC + 'S' + *Sigma*; (d) *470 h at 550°C* NbC + 'S' + *Sigma*; (e) *1000 h, sigma is strongest pattern*; (f) *Synthesized 'S' phase*

increase in hardness accompanying embrittlement. It may be said, therefore, that although there is a movement in transition temperature which may be due to a temper embrittlement type of effect, a major part of the change in the impact transition curve is caused by some other process.

The '475' type of embrittlement is characterized by the maintenance of hardness at a fixed level over prolonged periods of re-heating in the critical range.[3] Figure 3 indicates that the present steel showed a decline in the hardness with time at 550°C after an initial peak had been reached; this effectively eliminates '475' embrittlement.

The formation of sigma phase has long been associated with severe loss of impact strength. Present results show that sigma does form, but that over 100 h ageing at 550°C is necessary to produce detectable quantities. While, therefore, sigma is probably responsible for the continued embrittlement at long heating times at 550°C, it cannot explain the rapid hardening and embrittlement at short times and lower temperatures.

Only a precipitation mechanism remains, therefore, to explain the gross modification of the impact and hardening curves which results when the steel is aged. In general, the hardness results obtained are consistent with a solution and precipitation mechanism. Figure 1 suggests that maximum hardening occurs at 450°C. Softening at higher temperatures can be ascribed either to the formation of an incoherent precipitate or to the growth and coalescence of precipitate particles. With regard to the impact results obtained it is difficult at this stage to decide whether ageing modified these in a manner which would be characteristic of a precipitation process; this question will, however, be referred to again later.

Electrolytic extraction combined with chemical and X-ray analysis has revealed the presence of two phases, 'S' phase and niobium carbide, either or both of which could contribute to the embrittlement on ageing after an initial treatment at 800°C. The emphasis in the present study was directed towards discovering the effects of the new 'S' phase in relation to hardening and embrittlement. To do this a laboratory-prepared cast C containing only a low silicon content was compared with a cast D prepared under identical conditions and containing $2\frac{1}{2}$%Si.

TABLE II Composition of synthesized 'S' phase

Element	Si	Ni	Mn	Cr	Fe
Wt-%	13·3	50·0	8·0	15·5	10·0
At-%	23·8	44·5	7·6	15·1	9·1

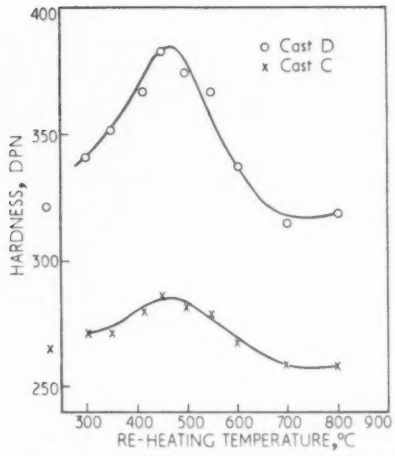
RESULTS: LABORATORY-PREPARED CASTS

Using an initial treatment at 800°C, hardness/reheating curves were prepared. Figure 15 shows these results, from which it is evident that the reduction in silicon content has lowered the general hardness level and also substantially reduced the hardness peak at 450°C.

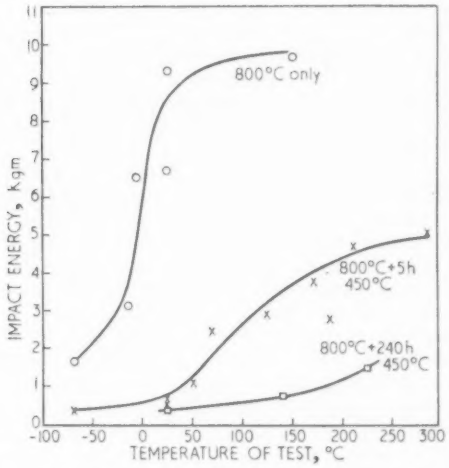
Again, using the 800°C initial treatment the effect of ageing at 450°C on hardness and room temperature impact strength was studied. Figure 16 gives the results and shows that the cast without silicon exhibits hardening and embrittlement at a very much reduced rate.

TABLE III 'd' spacings of 'S' phase lattice parameter 11·150 Å

Intensity	'd' observed	$h^2+k^2+l^2$	'd' corrected
VVF	2·784	16	2·787
F	2·278	24	2·276
S	2·143	27	2·144
VS	1·970	32	1·971
M	1·882	35	1·885
VF	1·858	36	1·858
F	1·763	40	1·763
F	1·701	43	1·700
VF	1·680	44	1·681
VVF	1·487	56	1·490
VF	1·452	59	1·452
F	1·315	72	1·314
F	1·288	75	1·287
M	1·224	83	1·224
VVF	1·216	84	1·216
VVF	1·170	91	1·169
F	1·139	96	1·138
M	1·122	99	1·120
VF	1·079	107	1·078
VF	0·9855	128	0·9856
F	0·9750	131	0·9741



15 *Hardness as a function of re-heating temperature, casts C and D, initially in the hot-rolled condition*



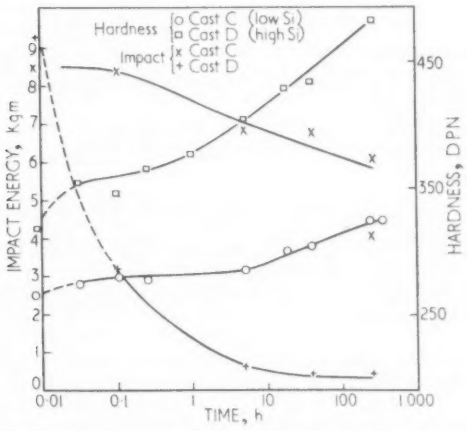
17 *Transition curves of cast D after initial treatment at 800°C and ageing at 450°C*

The change in impact transition curves with ageing at 450°C is illustrated by Figs.17 and 18 in which it was found that the low silicon cast showed a very much different behaviour from the control cast D.

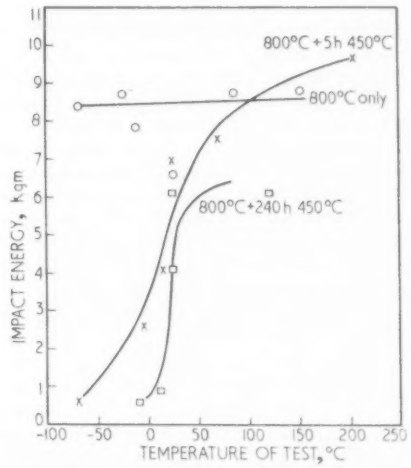
DISCUSSION

The experimental work described leads to two main conclusions. First, the embrittlement and hardening experienced on short-time ageing is due to a precipitation reaction and possibly a temper embrittlement type of effect, the former involving either or both of the compounds niobium carbide and the previously unreported 'S' phase. Second, after a long period of heating at an appropriate temperature, embrittlement appeared to be sustained by the formation of sigma phase. Having noted the possibilities with regard to short time embrittlement further interest was directed towards assessing the contributions made to embrittlement by the 'S' phase precipitate. To do this a cast with a low silicon content was prepared under laboratory conditions and its ageing characteristics compared with a silicon-bearing cast made under identical conditions. The results shown in Figs.15 and 16 indicate that after an initial treatment at 800°C the low silicon content cast showed only a slight hardening at 450°C while the cast containing 2½%Si was capable of developing a considerable effect. The small magnitude of the hardening in the low silicon cast not only demonstrates the necessity for silicon to be present to produce appreciable hardening but also indicates that there can be little hardening due to carbide precipitation with an 800°C initial treatment. As this situation is most probably connected with the low solubility of niobium carbide at 800°C this initial treatment was used extensively, as mentioned earlier.

The movement of the impact transition curves is also of considerable interest. Figure 17 shows that using the 800°C initial treatment, ageing cast D for a relatively short period causes a movement of transition temperature and a general lowering of the impact strength at all positions on the curve. As the hardness



16 *Effect of ageing at 450°C on impact strength and hardness, casts C and D, initially treated at 800°C. All tests at room temperature*



18 *Transition curves of cast C after initial treatment at 800°C and ageing at 450°C*

results of Figs.15 and 16 showed that little NbC precipitation occurs under the conditions investigated, the general lowering of impact strength produced can only be due to the precipitation of 'S' phase, while the increase in transition temperature may be due to either or both 'S' phase and a temper embrittlement type reaction. Impact transition curves for the cast low in silicon show that short times of ageing again produce a movement in transition temperature but have no effect on the general strength. The inference is therefore that the general modification of the transition curve is due to 'S' phase and that some, if not all, of the transition temperature movement is due to some form of temper embrittlement.

Having considered the hardening and embrittlement effects of 'S' phase it is now possible to examine in more detail some of the results obtained with the commercial casts. Figure 2 shows that around 680°C there is a narrow critical range of treatment over which the steel is less susceptible to embrittlement on subsequent ageing than at higher or lower temperatures. Retained austenite measurements (Fig.10) reveal that in this critical range there is a considerable amount of austenite retained. That this austenite is not directly responsible for the increase in impact properties when the as-rolled material is reheated is shown by comparing Figs.1 and 10. These show that for a large variation in austenite content between the 680° and 800°C reheated conditions there is only a small variation in impact strength.

The more likely explanation of the effect of reheating the steel in the region of 680°C is that, at this temperature, precipitating 'S' phase and carbide are heavily overaged, or in solution, while temper embrittlement, if it occurs at all, is inoperative. Owing to the insolubility of massive carbide it is not possible to say whether carbide has redissolved after a treatment at 680°C or whether it is in the overaged condition. On the other hand electrolytic extraction of steel treated at 680°C failed to produce any 'S' phase. This indicates that 'S' phase has gone into solution at 680°C. Having suggested that this is so, it is necessary to indicate why a subsequent treatment at say 550°C does not again allow 'S' phase to precipitate and cause short-time embrittlement. The following explanation of the effect is offered. On re-heating to the critical region, which dilatometer results showed to be two-phase, a small amount of austenite forms. Austenite partitioning elements such as nickel diffuse into it and promote stability on cooling. Ferrite partitioning elements such as silicon remain in the matrix. In this way it can be readily visualized that 'S' phase is effectively prevented from reforming on subsequent ageing, since its nickel constituent is effectively held in the stabilized austenite and silicon in the ferrite. When heating is at 800°C however, the structure is fully austenitic and nickel and silicon are uniformly dispersed; there is, therefore, little tendency for partition and so 'S' phase is again able to form and produce hardening.

Sigma phase and 'S' phase relation

The times required for production of sigma phase are short considering the low chromium content and the absence of cold work.[4–6] This leads to the question as to whether the acceleration of sigma formation is due to the presence of 'S' phase. Pryce *et al.*[7] suggested that the precipitation of $M_{23}C_6$ accelerated the appearance of sigma due to the local high concentration of chromium from the carbide. In the present case the precipitate is high in nickel which would tend to oppose the formation of sigma. On the other hand it is possible that the local depletion of nickel around precipitated particles coupled with the high matrix content of silicon may have some influence in initiating sigma phase.

CONCLUSIONS

1. The embrittlement of a 12%Cr–4%Ni steel after short periods of heating below 600°C was found to be due to precipitation hardening and possibly a temper embrittlement type of phenomenon.
2. A previously unreported phase, designated 'S', was associated with the precipitation hardening and embrittlement; its maximum effect appeared to be exhibited on ageing at about 450°C. It appeared to be in solution at 680°C.
3. Niobium carbide was present; no attempt was made to assess its precipitation characteristics.
4. Long times of heating at 550°C were found to cause the formation of sigma phase although the nominal composition was such as to make this seem unlikely. Further embrittlement resulted from this reaction.
5. 'S' phase approximates to M_3Si and does not appear to have been previously reported. In the general formula M can represent a combination of nickel, chromium, iron, and manganese.

ACKNOWLEDGMENTS

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Kinetics of first-stage graphitization in commercial white irons

J. Burke

SYNOPSIS

The time exponent in the rate equation for isothermal, first-stage graphitization in commercial white cast irons has been determined from published and new experimental data and found to be in the range 1·2–2·9. The exponent for comparable high-purity alloys has been shown previously to be 4·0, which has been interpreted in terms of a model in which carbide solution is the rate-limiting step. It is suggested that in commercial alloys, control is exercised by a diffusion process. Possible reasons for the difference are discussed. 1746

INTRODUCTION

THE KINETICS of first-stage graphitization in Fe–C–Si alloys have been the subject of a number of recent investigations.[1–4] The data is consistent with a model in which the rate of growth of the graphite nodules is controlled by the rate at which cementite dissolves in the austenite.[2] This theory predicts that the growth curves (the diameter of the largest visible nodule as a function of time of annealing) should consist of an initial stage in which the rate of growth decreases and a second stage in which it is substantially constant. The experimental curves obtained by Brown and Hawkes[5] using commercial white irons did not conform to this requirement, suggesting that a difference exists between the kinetics of first stage graphitization in commercial alloys and in high purity alloys. This observation prompted a reassessment of the available kinetic data for commercial irons and some further rate measurements on these materials.

KINETICS OF GRAPHITIZATION

First-stage graphitization in high purity white cast irons conforms to an equation

$$y = 1 - \exp -(t/k)^n \quad \ldots\ldots(1)$$

where k is a constant which varies with the temperature, composition, etc. and y is the fraction transformed at time t. The index n was found to be constant over wide ranges of temperature and composition, being 4·0 for the first 50% of the transformation, thereafter decreasing to about 2·5.[1, 2, 4] The value of n was an important feature of the argument leading to the theory that the growth of graphite nodules in these high purity alloys is controlled by the rate of solution of the cementite.[2] Thus a simple method of comparing commercial and high purity alloys is to compare the values of n, evaluated from the gradients of graphs of log log $(1/1-y)$, against log t.[1]

TIME EXPONENT IN THE RATE EQUATION

Of the many papers dealing with commercial alloys the results of Zeigler *et al.*[6] and Ferry[7] have been selected for discussion since they were obtained by dilatometric methods comparable to that used by Burke and Owen[1] for the high purity alloys.

Zeigler's data, plotted as above, are shown in Fig.1. The plots are linear in all cases up to about 50% graphitization. In two of the four results the experimental points corresponding to the second half of the transformation also lie on a second straight line, the gradient of which is less than that obtaining in the first half. Similar reductions in slope (and thus in n) have been noted in other reactions[8] and for the first-stage graphitization in some high purity alloys.[4] For graphitization at 1040° and 980°C linear plots are not obtained after 50% transformation.

Values of n calculated from the initial slopes are listed in Table I. They lie in the range 1·32–1·50.

An alternative equation

$$\left(\frac{y}{1-y}\right) = K_1 t^m \quad \ldots\ldots(2)$$

has sometimes been found to be more satisfactory than equation (1).[7, 9] It differs from the former only in the allowance made for the impingement of adjacent particles of precipitate; the significance of the time exponent is the same in both cases. If equation (2) is applicable log $(y/1-y)$ is a linear function of log t and the gradient of the graph is equal to m. Zeigler's data plotted according to equation (2) are shown in Fig.2. Good linear plots are obtained in all four cases over the entire reaction. Thus, in this case, the appropriate impingement factor appears to be $(1-y)^2$. The values of m determined from Fig.2 are tabulated in Table I, and lie in the range 1·5–1·8. Thus the value of the time exponent in the rate equation is relatively insensitive to the method of representing the data.

The rate of graphitization in a wide range of commercial cast irons was measured by Ferry.[7] He found that equation (1) was acceptable up to about 50% transformation; whereas equation (2) was a satisfactory representation of the data throughout the process. He interpreted the result in terms of the latter. No systematic variation of the value of the index with

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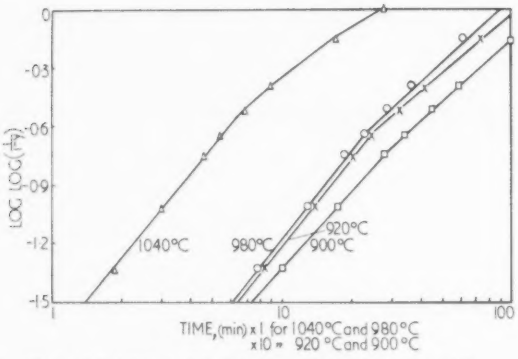
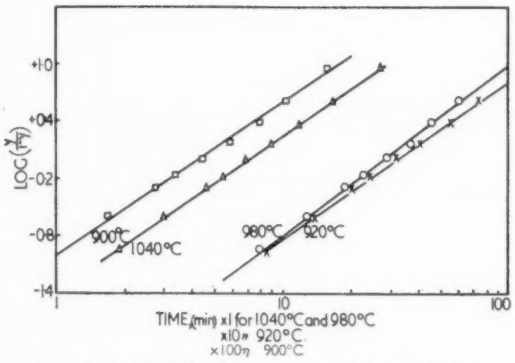
The author is with the Department of Metallurgy, Liverpool University.



1 *Data of Zeigler* et al.[6] *plotted according to equation (1)*



2 *Data of Zeigler* et al.[6] *plotted according to equation (2)*

temperature is apparent and so his results have been averaged for each composition. The values vary with composition but the variation cannot be correlated with variations in any one element. The range of values is 1·8–2·9.

To supplement the above data, the rate of first stage graphitization in two commercial blackheart type white irons was measured using a dilatometric technique. The compositions of the alloys are given in Table I. The apparatus did not permit rapid heating of the sample, the time required to raise the specimen from room temperature to about 900°C being about 15 min. A small amount of graphitization occurred during this period and so the initial stages of the rate curves were a little uncertain. To give weight to this athermal reaction zero time was taken to be the start of the heating. The selection of the dial gauge reading corresponding to zero reaction at the reaction temperature was arbitary due to the absence of any true incubation period. However, this choice does not influence the shape of the rate curve and thus in no way affects the value of the index.

The reaction curves for the two irons at 840°–925°C showed no unusual features. Plotting the double logarithmic graph according to equation (1) gave the result shown in Fig.3; plotting according to equation (2) gave the results shown in Fig.4. Considering Fig.3, it can be seen that the best way of representing the data is two straight lines, the first being applicable from 0–50% graphitization and the second, of a reduced gradient, from 50% onwards. However, for sample no.123 at both temperatures, the fit of the experimental points to a straight line in the second half of the reaction, is poor. Considering Fig.4, straight lines are obtainable for three curves up to the mid-point of the reaction, after this the fit is poor in all cases. The values of n and m for the initial stages of graphitization are given in Table I. Again they differ little; the range is 1·2–1·8.

DISCUSSION OF RESULTS

Two methods of representing the isothermal graphitization data have been examined. It appears that neither equation (1) nor equation (2) is universally applicable and it is necessary to test each individual curve to find the best fit. In some cases neither is very good but it is noted that the deviation of the experimental points from the linear relations predicted by the two equations is in opposite directions. This suggests that the impingement factor is of the form $(1-y)^x$ where x can take values from 1–2.[1, 9]

The values of the time exponent are little affected by the choice of impingement factor, as can be seen by comparing the values of n and m. The significance of the exponent is the same in both cases and it is thus permissible to discuss the implications of these values, without regard to the method of derivation.

It has been shown[2] that if the growth equation is of the form

$$R = K_g t^a \quad \ldots\ldots(3)$$

where R is the radius of a nodule at time t and K_g and a are constants, and the nucleation frequency is given by

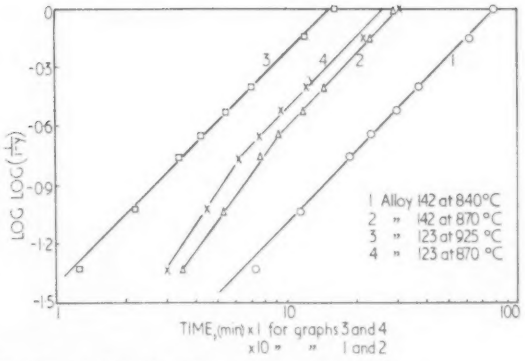
$$N = K_n t^b \quad \ldots\ldots(4)$$

where N is the number of nuclei per unit volume at t and K_n and b are constants, then for spherical nodules

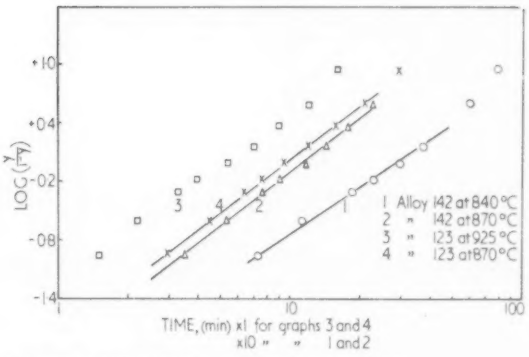
$$n \text{ (or } m) = 3a + b \quad \ldots\ldots(5)$$

TABLE I Values of *n* and *m* determined from Figs. 1–4

Composition, % C	Si	Mn	S	P	Temp., °C	*n*	*m*		Source
3·16	0·91	0·47	0·092	0·17	900	1·32	1·5		Zeigler[6]
					920	1·50	1·63		
					980	1·49	1·77		
					1 040	1·44	1·63		
2·80	1·05	0·35	0·15	0·10	850–1 000		2·85		Ferry[7]
2·92	0·91	0·32	0·19	0·09	850–955		2·90		
2·63	1·15	0·32	0·13	0·14	960–1 004		2·50		
2·46	0·97	0·26	0·12	0·07	900–950		2·22		
2·72	1·22	0·32	0·03	0·06	820–950		1·91		
2·62	1·26	0·31	0·10	0·07	850–960		1·81		
2·42	1·03	0·25	0·087	0·06	870	1·70	1·80	alloy 123	Present work
					925	1·20	...		
2·44	1·16	0·30	0·081	0·05	870	1·60	1·75	alloy 142	
					840	1·25	1·60		



3 *Present data plotted according to equation (1)*



4 *Present data plotted according to equation (2)*
Note: *points (3) do not give a linear plot and other three graphs are not linear after 50% graphitization*

It is generally assumed that the nucleation rate is constant; thus b=1 (this has been justified experimentally for some high purity[1, 3, 4] and commercial alloys.[5, 7] For diffusion controlled growth[10] a=$\frac{1}{2}$ which gives $n=2{\cdot}5$. For cementite solution or graphite crystallization controlled growth[2] a=1 and $n=4$%. Thus Ferry's results can be interpreted on the basis of diffusion controlled growth and an approximately constant rate of nucleation.[7] The results of Zeigler and those of the present investigation are lower than 2. This discrepancy cannot be explained on the basis of departure from spherical geometry as this leads to an increase in the index. The most likely explanation is that the nucleation was completed at a very early stage of transformation in which case b would approach zero. In both these investigations the rate of heating to temperatures was slow, allowing reaction to start before the true reaction temperature had been attained. It is to be expected that most of the nucleation was accomplished during this heating period. If this is so then these n values also indicate diffusion controlled growth.

Thus the general conclusion is that in the commercial cast irons considered, the rate of growth of graphite during first stage graphitization is controlled by a diffusion process in contrast to certain high purity alloys in which, it is believed, the solution of cementite is the slowest process. The analysis given by Birchenall and Mead[10] suggests that the controlling diffusion process is that of carbon in austenite. If this is so it follows that in the commercial alloys the diffusion of carbon is slower or the solution of cementite faster than in the corresponding high purity alloys.

At the moment it is not possible to advance any explanation of these effects which can be supported by known facts. It is tempting to attribute the differences in the two classes of alloy to supposed differences in impurity contents. A difficulty with this approach is that the effect of alloying additions on carbon diffusion is small, so slight differences in composition would have little effect on the diffusion coefficient of carbon, unless undetermined trace elements and gaseous impurities have a very pronounced influence. The present results could be rationalized if the rate of diffusion of carbon in austenite is retarded by impurities. As far as is known there is no data with which to check this point. However, if the effect of other interstitials is the same as that of carbon itself then the diffusion coefficient of carbon is increased by impurities.[11] Clearly, further speculation along these lines is not worth while until more data is available on rates of graphitization, diffusion, and solution of cementite.

There is an alternative line of argument. The amount of carbon provided by solution of the cementite depends upon its surface area which is governed by its form and distribution and the carbon content of the alloy and of the carbide. Furthermore, the diffusional flux is a function of the diffusion length which in the case of graphitization depends upon the number and size of nodules present. Thus it is possible to vary both diffusion and solution fluxes by variations in (*a*) composition, and (*b*) any factor which influences the form of either the cementite or graphite, such as rate of cooling, degree of superheating, etc. The rate of growth of the graphite is determined by the slowest of these two steps. The origin and history of high purity and commercial alloys differs considerably. It is tentatively suggested therefore, that the differences in graphitization characteristics arises from microstructural variations of this kind.

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Thermodynamics of mixtures of ferrous sulphide and oxide

E. W. Dewing and F. D. Richardson

SYNOPSIS

Measurements have been made between 1100° and 1443°C of equilibria between molten mixtures of iron sulphide and oxide, and gases developing known partial pressures of oxygen and sulphur. The melts contained ferric iron at cation fractions up to 0·11 and the O/S ratios ranged from 0·15 to 1·93. The equilibrium constant varied with the fraction of ferric iron and the temperature according to the equation

$$\log \frac{N\mathrm{O}^{--}}{N\mathrm{S}^{--}}\left(\frac{p\mathrm{S}_2}{p\mathrm{O}_2}\right)^{\frac{1}{2}} = \frac{5460}{T} - 0{\cdot}340 + \frac{2362\,N\,\mathrm{Fe}^{+++}}{T}$$

where $N\,\mathrm{Fe}^{+++}$ *is the cation fraction of ferric iron and is equal to* $n\mathrm{Fe}^{3+++}/(n\mathrm{Fe}^{+++}+n\mathrm{Fe}^{++})$. *The pickup of sulphur by the charge from furnace gases during melting in the open hearth is considered in the light of the results. Absorption by melting oxide produced by the furnace gases appears to be the most important mechanism of pickup. The net pickup appears to be determined by the amount of oxide produced, the sulphur concentration in the charge and the oxygen potentials and sulphur contents of the impinging gases.* 1749

INTRODUCTION

MIXTURES OF OXIDES AND SULPHIDES take part in many metallurgical processes, yet no measurements have been made of their thermodynamic properties. In steelmaking, for instance, mixtures of ferrous oxide and sulphide are almost certainly formed on scrap during melting in the open hearth, and similar mixtures are probably formed on the surfaces of ingots when exposed to sulphur-containing gases in reheating furnaces. The important equilibrium can be represented by the equation

$$(\mathrm{O}^{--}) + \tfrac{1}{2}\mathrm{S}_2 = (\mathrm{S}^{--}) + \tfrac{1}{2}\mathrm{O}_2 \quad \ldots\ldots(1)$$

Mixtures of ferrous oxide and sulphide generally contain some ferric iron which usually increases with the oxide content. One is therefore interested to know whether the equilibrium constant for reaction (1) is influenced by the amount of ferric iron present, and whether the activity coefficients of oxide and sulphide vary with their concentrations at fixed ferrous/ferric ratios.

Existing published information on the system FeO + FeS consists solely of phase diagrams.[1–3] These all show a simple eutectic with no solid solubilities, but they disagree on its temperature and composition. From the phase diagram of Giani[1] and the necessary heats of fusion, Chipman[4] has calculated that the mixtures are not far from ideal, i.e. a(FeO, FeS)$\sim$ 1·5N(FeO, FeS) at high dilution; the calculation is only approximate, however, due to uncertainty about the ferric iron content of the eutectic.

This paper reports the results of a study which has been made of equilibrium (1) between 1100° and 1433°C. The procedure adopted was to heat small samples of the condensed phase in a stream of gas made from N_2, S_2, and SO_2. These were mixed in proportions which gave the required partial pressures of oxygen and sulphur at the temperatures of the melts. When equilibrium had been attained the samples were quenched and analysed, so that the concentrations of oxide and sulphide could be established. The melts were held in platinum to avoid contamination by oxides such as alumina and magnesia, which dissolve readily in molten ferrous oxide. To prevent too much iron from entering the platinum, the oxygen potentials had to be substantially greater than those for the equilibrium Fe + 'FeO'; the ferric iron concentration in the melts was thus considerable and it increased steadily as the oxide content of the mixture increased.

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Dr Dewing is at Aluminium Laboratories, Ltd, Arvide, P.Q., Canada, and Professor Richardson is professor of extraction metallurgy at the Royal School of Mines, London, SW7.

EXPERIMENTAL PROCEDURE

Materials

The gas mixtures were made by bubbling nitrogen through molten sulphur as described elsewhere[5] and adding sufficient sulphur dioxide to give the required oxygen pressure. Ferric oxide was used as the source of ferrous oxide in the experiments, and it was prepared by igniting Analar ferrous ammonium sulphate.

Procedure

The apparatus and procedure were similar to those already described by the authors for bringing small amounts of molten calcium silicate into equilibrium with gases containing sulphur.[5] Two 100 mg samples of ferric oxide were supported in two small conical platinum spirals and heated in a mixture of nitrogen

TABLE I Compositions of liquid Fe–O–S mixtures

Run no.	Temp., °C±2	ipS_2 atm	$ipSO_2$ atm	N_{pt}/N_{Fe}	Mole-%Fe	Mole-%O	Mole-%S	N_O/N_S
...	1206	0·0044	...	...*	50·5	...	49·5	...
34	1206	0·0044	...	0·0234	50·9	...	49·1	...
30	1206	0·00430	0·00124	0·0098	49·99	6·60	43·40	0·152
31	1206	0·00442	0·00203	0·0071	50·34	8·03	41·61	0·193
29	1206	0·00421	0·00218	0·0063	49·38	9·52	41·13	0·232
32	1206	0·00409	0·00399	0·0043	49·83	11·86	38·31	0·309
27	1206	0·00416	0·00474	0·0064	49·25	13·00	37·76	0·344
40	1206	0·00442	0·00742	0·0035	49·65	14·88	35·47	0·420
26	1206	0·00427	0·00742	0·0058	49·48	15·44	35·09	0·440
41	1206	0·00364	0·01087	0·0040	49·00	18·95	32·05	0·592
44	1206	0·00347	0·00828	0·0038	49·40	18·81	31·79	0·592
43	1206	0·00399	0·01607	0·0037	50·01	20·84	29·14	0·715
42	1206	0·00371	0·01187	0·0026	49·21	21·76	29·02	0·750
39	1206	0·00408	0·0217	0·0031	48·76	25·10	26·14	0·960
35	1206	0·00422	0·0262	0·0006	48·95	26·27	24·77	1·060
38	1206	0·00396	0·0283	0·0023	48·70	27·01	24·29	1·113
36	1206	0·00379	0·0505	0·0014	48·97	31·54	19·50	1·620
33	1206	0·00498	0·0891	0·0005	48·67	33·80	17·55	1·927
48	1431	0·00403	0·0258	0·0006	49·47	33·41	17·09	1·955
49	1435	0·00371	0·00866	0·0035	49·84	25·86	24·32	1·063
80	1100	0·00446	0·0402	0·0024	48·68	23·14	28·20	0·821

* Alumina crucible as container instead of platinum spiral.

TABLE II Results for liquid Fe–O–S mixtures

Run no.	pSO atm	pS_2 atm	pSO_2 atm	pO_2 $\times 10^{10}$ atm	$(pS_2/pO_2)^{\frac{1}{2}}$ $\times 10^{-3}$	log K
30	0·00010	0·00428	0·00119	0·195	14·8	3·353
31	0·00013	0·00439	0·00197	0·319	11·7	3·355
29	0·00014	0·00418	0·00211	0·350	10·93	3·404
32	0·00018	0·00404	0·00390	0·657	7·84	3·387
27	0·00020	0·00411	0·00464	0·775	7·28	3·386
40	0·00026	0·00436	0·00729	1·18	6·07	3·406
26	0·00026	0·00421	0·00729	1·20	5·91	3·415
41	0·00030	0·00357	0·0107	1·92	4·31	3·407
44	0·00026	0·00341	0·00815	1·50	4·78	3·451
43	0·00037	0·00390	0·0159	2·73	3·78	3·432
42	0·00031	0·00363	0·0117	2·08	4·18	3·496
39	0·00043	0·00397	0·0215	3·66	3·30	3·500
35	0·00048	0·00410	0·0260	4·35	3·07	3·512
38	0·00049	0·00384	0·0280	4·84	2·82	3·496
36	0·00064	0·00363	0·0502	8·93	2·02	3·514
33	0·00092	0·00475	0·0887	13·8	1·86	3·553
48	0·00160	0·00373	0·0250	220	0·412	2·906
49	0·00090	0·00348	0·00821	74·7	0·682	2·860
80	0·00090	0·00424	0·0397	0·676	7·92	3·813

and sulphur until molten. The composition of the gas stream was then adjusted to that required for the experiment and the liquid samples were brought into equilibrium in 2–3 h. It was necessary to use these open spirals as the FeO+FeS melts always crept out of platinum crucibles. The platinum became embrittled by absorption of iron, and a little platinum sulphide dissolved in the melts, 2 mole% in the high sulphide melts and 0·06 mole% in the high oxide.

Analysis

The platinum spiral was unwound and the sample, which broke away from it, was crushed in an agate mortar and weighed in an ignited alumina boat. It was then heated in hydrogen at 850°C for 4 h, the H_2S produced being absorbed in zinc acetate solution. The residual sintered metal, which could normally be detached cleanly from the boat, was weighed and treated with acid: the insoluble platinum was collected and weighed. Next, 25 ml of $N/10$ iodine were added to the zinc acetate solution which was then acidified with concentrated HCl and titrated with $N/10$ thiosulphate. It was found necessary to calibrate the method by reducing samples of FeS in hydrogen and determining the weight loss. Iron, sulphur, and platinum were thus determined directly and oxygen by difference. It is considered that the platinum was present as PtS and sulphur equivalent to it has been subtracted in working out the compositions; the correction is, in any case, very small.

RESULTS

The results are given in Tables I and II: ipS_2 and $ipSO_2$ are the pressures of the ingoing gases: pS_2 and pSO_2 are the pressures in the hot zone where some SO is produced (5). The results are shown in Fig.1 where log K for reaction (1), i.e.

$$\log \frac{NO^{--}}{NS^{--}} \cdot \left(\frac{pS_2}{pO_2}\right)^{\frac{1}{2}}$$

is shown as a function of the ferric cation fraction N Fe^{+++}.

The systematic and random errors on ipS_2 and $ipSO_2$ were each about 2% and the errors in the analysis of the melts introduced a 2% error in NO^{--}/NS^{--}. K should therefore be accurate to about 3%(s.d.). The values of N Fe^{+++} calculated from the total iron and sulphur concentrations are much less accurate, because an error of 0·001 in the atom fraction of iron in the melt leads to an error of about 0·008 on N Fe^{+++}. The scatter in Fig.1 is consistent with a reasonable s.d. of 0·002 on the atom fraction of iron (corresponding to an error of ±0·3 on its wt-%) in addition to the errors already mentioned.*

DISCUSSION

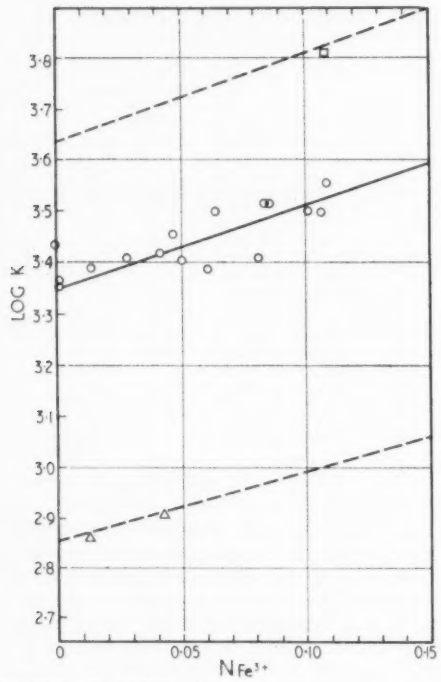
Equilibrium data

Figure 1 shows that log K can be represented as a linear function of the cation fraction of ferric iron. Log K is also a linear function of the anion fraction of oxygen because in these experiments the values of pO_2, and hence the concentrations of ferric iron, increased with the oxide contents of the melts. It is therefore not possible to tell whether the change in K is caused by the change in the ferric iron concentration or by the change in the ratio of oxygen to sulphur in the melt. If caused entirely by the latter, then at high dilution the activity coefficients (Raoultian) of FeO or FeS, would equal 1·56: at N=0·5, they would equal 1·12.†

One would, however, expect log K to change with the cation fraction of ferric iron, because the heat changes (per g-atom of oxygen ion) associated with reaction (1) vary greatly with cation size. Figure 2 shows, for example, the values of $\Delta H^\circ_{298°K}$ for the conversion of crystalline oxides to sulphides as a function of the ionic radii of oxygen (1·32 Å), sulphur (1·74 Å), and the cation concerned (r). The radius of the ferric ion is 0·67 Å, so that ΔH° would be about 56 Kcal if an Fe_2S_3 existed: ΔH° for the ferrous ion is 42 Kcal so the difference is 14 Kcal. If the heat for reaction (1) is taken as varying proportionately with composition by this same amount, ferric iron at a

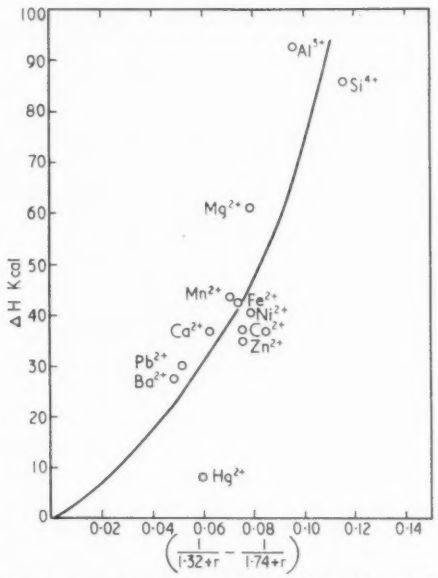
* When this work was done the importance of the ferric iron content was not appreciated; therefore attempts were not made to devise a method of analysing directly for this constituent in the presence of sulphur.

† The actual deviations from the ideal might be greater than these, for the effect of the changes in the concentration of ferric iron might be to offset the effect of the non-ideal mixing of oxide and sulphide.



□1100°C ○1206°C △1433°C

1 *Log K shown as a function of the cation fraction of ferric iron*



2 *Heats of conversion at 298°K of crystalline oxides to sulphides per g-atom of oxygen ($\frac{1}{2}O_2$) and sulphur (rhombic) shown as a function of the cation radius, r*

cation fraction of 0·1 should make ΔH° 1·4 Kcal more positive, and hence change log K by about 0·2 at 1206°C. The observed change is 0·16 (*see* Fig.1) so it seems reasonable to attribute the variation in K entirely to the effect of the cations and not to any lack of ideal mixing of the anions*. If this is done one may write

$$\log K\ (1206^\circ C) = 3{\cdot}35 + 1{\cdot}6N\ Fe^{+++} \quad \ldots\ldots(2)$$

To derive an equation for the whole temperature range 1100° – 1433°C, it has been assumed that the effect of ferric iron on log K arises from the heat term referred to above, so its magnitude should be inversely proportional to the absolute temperature: $2362/T$ therefore takes the place of 1·6 in equation (2). The data for all three temperatures then fit the equation+.

$$\log K = 5460/T - 0{\cdot}340 + (2362/T)N\ Fe^{+++} \quad \ldots\ldots(3)$$

which give the three straight lines in Fig.1. For the limiting case in which ferric iron is absent, this equation gives

$$\Delta G^\circ_{1373-1706} = 25\,000 - 1{\cdot}54T$$

for the reaction

$$FeO(liq.) + \tfrac{1}{2}S_2 = FeS(liq.) + \tfrac{1}{2}O_2.$$

This agrees within the error limits with the equation

$$\Delta G^\circ_{1642-2000^\circ K} = 25\,280 - 2{\cdot}41T$$

derived for this same reaction from other equilibrium and thermal data by Fincham and Richardson.[7]

It is interesting to note that equation (3) leads to a value of 0·12 for the sulphide capacity[7] of 'FeO' in equilibrium with iron at 1600°C, in close agreement with the value of 0·11 which can be derived from the measurements of Bardenheur and Geller.[8] It also gives a value of 0·19 for the sulphide capacity of 'FeO' with a ferric cation fraction of 0·04 at 1770°C: this may be compared with the values of 0·125 and 0·095 which can be derived for slags containing about 89 wt-%FeO 4 wt-%Fe_2O_3, and 7 wt-%MgO from the measurements made by Grant and Chipman[9] at 1750° and 1787°C respectively. If, however, allowance is made for the effect of the Mg^{++} ion in these slags (*see* Fig.2), the calculated sulphur capacity comes down to about 0·13 and agreement is very satisfactory. St Pierre and Chipman[10] have studied this same equilibrium by bringing iron oxide melts into equilibrium with gas mixtures made from SO_2 and CO at temperatures from 1450° and 1600°C. Their melts, in which $N\ Fe^{+++}$ was about 0·32, absorbed a few at-% of S. The values of K which may be calculated from their results, and their calculated pressures of oxygen and sulphur, are 2·7 to 4·3 times greater than those which can be calculated from equation (3) above. The differences may be caused by failure of equation (3) at such high ferric iron contents, but may also be caused by errors in the sulphur pressures calculated by Chipman and St Pierre, for these have already been shown to be in doubt.[5]

Tentative application to the open hearth

Now that the sulphur holding properties of molten iron oxide have been quantitatively established, it is of interest to consider the mechanism of the pickup of sulphur by the charge from the furnace gases during melting in the open hearth. The metal throughout

* Recent work by Rosenqvist[6] indicates that the pseudo-binary system FeO+FeS is nearly Raoultian. More complex explanations of the variation of K with composition could be devised, but they are not necessary to account for existing data.

* Expressed in terms of the Flood–Grjotheim equation this would be $\log K = N\ Fe^{++}(5460/T - 0{\cdot}340) + N\ Fe^{+++}(7822/T - 0{\cdot}340)$.

melting is almost certainly protected by a film or layer of oxide which melts at about 1400°C, so that the extent to which sulphur is picked up by the charge is probably governed by the amount of sulphur which this oxide can abstract from the gases during its formation.

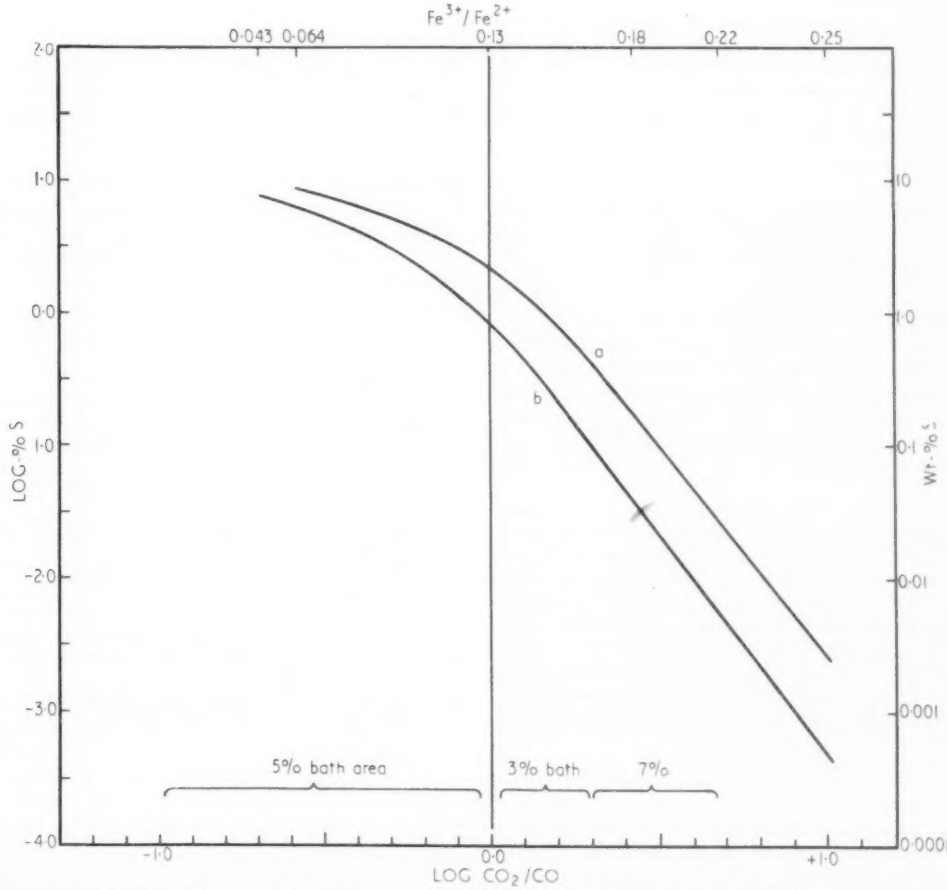
To obtain some idea of the amount of sulphur absorbed in this way, oxide drippings were collected in an iron spoon inserted into a 100-ton OH furnace, fired with oil containing 1·2%S. Samples were collected at different times from a melting rail and from a melting plate, each about one-quarter of the way across the furnace from the door at the outgoing end. Owing to obvious practical difficulties it was not possible to get samples from material melting in the centre of the furnace. The analyses of the oxides collected are given in Table III.* If it is assumed that the ferric/ferrous ratio in the drippings, reflects the CO_2/CO ratio obtaining at the places where they were formed in the furnace, one can calculate the sulphur content which would be reached, if the drippings were to come to equilibrium with the gases. One needs to use equation (3) above, the data of Darken and Gurry[12] on the composition of molten iron oxides in equilibrium with various CO_2+CO gas mixtures, and the available thermodynamic data on the gaseous sulphur compounds SO_2, SO, COS, etc. Values for the CO_2/CO ratios in equilibrium with the drippings, their melting points, and the sulphur contents for equilibrium at 1400° and 1500°C are given in Table III. In view of the fact that the drippings must run off the metal and be collected somewhat above their melting points, it appears that the calculated sulphur contents are not very far removed from the measured values.

TABLE III Oxide drippings collected in a basic OH furnace

Drip from	Analysis, wt-% FeO	Fe_2O_3	S	Approx. melting point, °C	Calculated equilibrium data CO_2/CO 1400°C	1500°C	S, wt-% 1400°C	1500°C
Plate	68·8	29·0	0·023	1425	4·8		0·027	0·0056
Rail	74·3	23·5	0·079	1400	2·6		0·20	0·040

It has therefore been considered worthwhile to calculate the sulphur contents of the molten iron oxides, which would be in equilibrium with gases of various CO_2/CO ratios resulting from the combustion of 1·2%S oil. The calculations take account of

* As the SO_2 content of the combusted furnace gases would be about 0·064%, application of Herty's empirical relationship[11] for the sulphur content of the drippings gives 0·070 wt-%.



3 *Sulphur contents of iron oxide melts in equilibrium with gases arising from 1·2%S oil at various degrees of combustion at* (a) *1400° and* (b) *1500°C. Curves extend to the* CO_2/CO *values in equilibrium with pure iron*

the ingoing steam as well as air, and allow for the formation of H_2S, COS, SO, and S, as well as SO_2. The first three become important under the more reducing conditions. The results are shown in Fig.3. It is evident that the danger of sulphur pickup decreases markedly with rise in temperature, and very markedly with increasing degree of combustion of the gases.

Studies that have been made of the mixing of gases in the open-hearth furnace, show that with a flat bath[13] the CO_2/CO ratio may commonly be less than 1·0:1 over 5% of the bath area, and between 1·0 and 5·0:1 over a further 10% or so. If a similar distribution of ratios is assumed to obtain during melting, when piles of cold charge are present, and if the oxides come near to equilibrium with the gases at 1400° to 1500°C, one can attempt to estimate the sulphur which would be picked up, provided the amount of oxide produced during charging and melting is known. During this period about 2·5 tons of oxygen can be absorbed from the furnace gases with a 100-ton cold charge.[13] This is taken either by direct oxidation of the metal (i.e. by production of ferrous oxide which may then be reduced by the carbon, phosphorus etc., in the metal) or by the oxidation of ferrous iron to ferric in slag already produced. The first mechanism entails sulphur pickup, the latter does not. It seems reasonable to take the iron oxide produced directly as that equivalent to half the oxygen absorbed, i.e. 5·6 tons of ferrous oxide.

If the rate of production of iron oxides is taken as uniform over the whole area of the bath, over the most dangerous 5% where the ratio CO_2/CO is less than 1:1, the 'equilibrium' sulphur pickup would be about 34 lb at 1400°C and 26 lb at 1500°C. These quantities are arrived at by the equation

$$S\ \text{lb} = 5 \times 10^{-2} \times W \times S\% \times 10^{-2}$$

where W is the weight of iron oxides produced over the whole bath and S% is the average equilibrium sulphur content for oxygen potentials ranging from CO_2/CO, 1:1 to equilibrium with 'FeO'+Fe, i.e. 5·4% at 1400°C and 4·1% at 1500°C from Fig.3.

From Fig.3 one can similarly estimate that over the 10% of area where the ratio CO_2/CO rises from 1 to 5·1, 2 to 5 lb or so of S might be picked up depending on the temperature: over the remainder of the bath some 6 lb might be lost if the oxides were produced from typical metal containing about 0·06%S. The total estimated pickup by the charge is thus some 20 to 30 lb.

Pickup of 20 to 60 lb of sulphur has been reported[13, 14] during charging and melting in such furnaces with 2·5%S oil, so one might expect a net pickup of 10 to 30 lb with 1·2%S present. Much of the variation reported may be due to errors in making the necessary sulphur balances, but substantial variations are probably to be expected, on account of differing temperatures, and of variations in the charging schedules and the piling of the scrap. The agreement between the estimated and reported values for sulphur pickup, lends support to the assumptions made in arriving at the estimate. It is thus a reasonable working hypothesis that the melting metal is protected by melting oxide, and that absorption of sulphur by this oxide is the most important mechanism of pickup. It also seems that the extent of pickup is mainly determined by the temperature of the oxide and the oxygen and sulphur potentials of the gases, and that rather less than the 'equilibrium' amounts of sulphur are absorbed. The low oxygen potentials obtaining at the Fe/'FeO' interfaces do not appear to be controlling, otherwise much greater absorptions would probably be found. It looks very much as though the main pickup occurs where incompletely combusted gas impinges on the metal, so that the shorter the flame and the more rapidly combustion is completed, the less sulphur will be absorbed Further analysis suggests that with fuels containing less than 0·5%S, it may be possible to avoid any pickup during melting and even to lose sulphur to the furnace gases from a charge containing about 0·6%S. This is broadly in line with Herty's findings[15] that in his furnace experiments, tar or oil containing 0·75%S was 'neutral' to scrap containing 0·06%S. If more oxidizing conditions were to obtain over the centre of the bath than have been assumed in these calculations losses of sulphur from the charge during melting would be expected in the presence of correspondingly greater concentrations of sulphur in the oil.

ACKNOWLEDGMENT

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The location of Byrkeknott

A 15th-CENTURY IRON SMELTING SITE

R. F. Tylecote

SYNOPSIS

The account roll relating to the early 15th century smelting site known as Byrkeknott, in Weardale, Co. Durham, is one of the most informative documents dealing with the direct process. An attempt has been made to locate this site. An iron smelting site, answering to the description given in the roll, has been excavated and some metallurgical remains, which are datable to the 14th-15th centuries, have been found. There is a strong possibility that the site excavated is that of Byrkeknott, and on this basis an estimate of the yield has been made. 1757

HISTORICAL INTRODUCTION

IN THE OLD CHRONICLES and records of the See and Palatinate of Durham there are frequent references to the iron mines of Weardale, and the sale of iron afforded the bishops a fruitful source of revenue. The usual practice was for these mines to be farmed out together with the forests which supplied the charcoal. Bishop Langley, however, 'tried the experiment to work his own iron', and a suitable site beside a stream, was chosen to build a bloomery.[1]

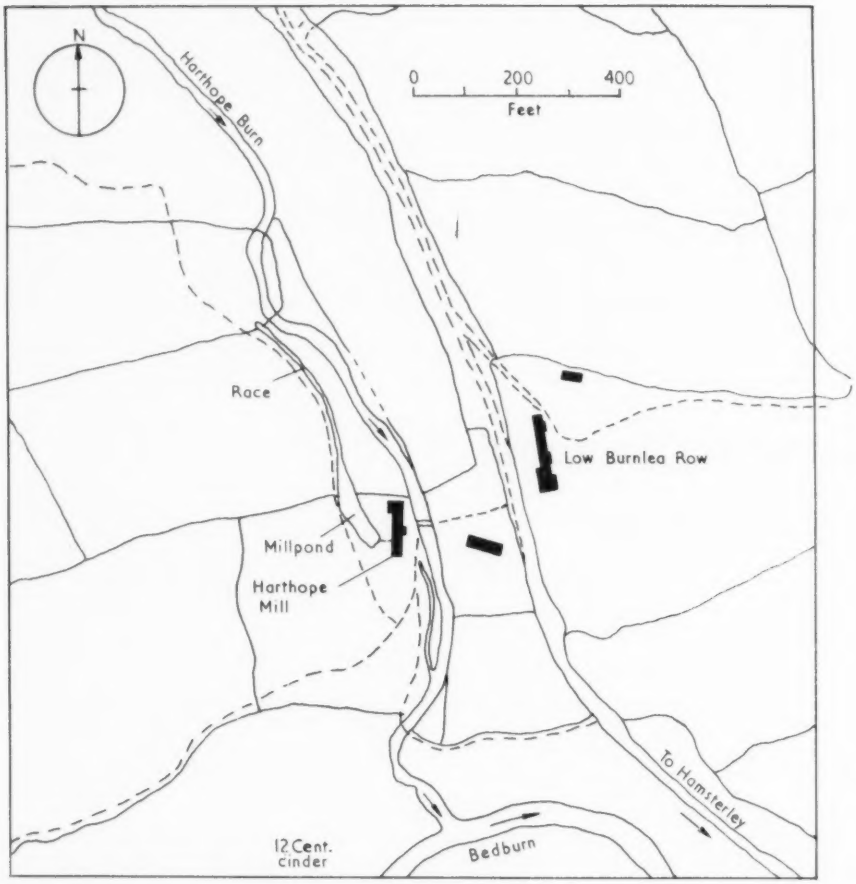
Many of Durham's records were destroyed in the 17th century and it is fortunate that an account roll[2] of Bishop Langley was preserved. This is one of the earliest surviving documents giving useful information about iron smelting. Lapsley, an American engaged in writing a history of the Palatinate of Durham, found it in the course of his research and transcribed it in 1899 under the title: 'The account roll of a fifteenth-century iron master'.[1] A detailed description is given of a newly erected bloomery at Byrkeknott, near Bedbourn in Weardale, Co. Durham, and of operations carried out in one year from November 1408–9. Only one earlier comprehensive account of a bloomery has been preserved, that for Tudeley near Tonbridge in Kent; the accounts cover two periods; from 1329–34, and from 1350–4.[3]

The Langley account roll states that the bloomery was erected at 'Byrkeknott juxta Bedbourne' and that the water-gate extended from 'Heribourne'. Both these names are now lost and no trace of them could be found in the records of the times.

Bedbourn was in early times divided into South and North Bedbourn. In Hatfield's Survey of 1345–87[4] South Bedbourn covered an area west of the Wear and north and south of Bedbourn River. North Bedbourn covered an area east of the Wear and the village itself was situated between Greenhead and Firtree. The survey gives the names of tenants holding land in the two parishes, and a few of these names occur in the account roll in connexion with the bloomery.

Today only the parish of South Bedburn remains. Bedburn village consists of a few houses, a hall, and a mill. The mill was known as 'Bedburn Forge' early in the last century and Lapsley drew the conclusion that 'Bedburn Forge' was the old Byrkeknott. The history of the mill goes back a very long time, but it does not

Manuscript received 12 August 1959.
The author is at the Department of Metallurgy, University of Durham.



1 *Map of area round Harthope Mill*

seem to have been used for metallurgical purposes, except in the 19th century. It is first mentioned in 1314 as being a fuller's mill,[5] and in 1551 there is a reference to a fulling mill at 'Hoppylandknottes'.[6] Early in the 18th century Bedburn Mill might have been used as a cornmill since a miller is recorded as having died there in 1741.[7] The records also show that a blacksmith lived at 'Bedburn Mill' in 1799. The mill itself was a bleachery in 1820, when it came into the possession of William Dodds, a manufacturer of edge-tools and shovels.[8] Later, in about 1860, it was used as a sawmill.[9] There is a mill-race about half a mile long, but no stream joining the river Bedburn upstream of the mill which could be identified with 'Heribourne'.

A survey of the area showed that barely half a mile to the east is a ruined mill known as Harthope Mill, near a small stream called Harthope Burn. Harthope Mill fits the description of Byrkeknott much better than Bedburn Mill. The millrace is only 100 yd long and we know that one mason and four labourers were employed to construct it and to line part of it with stone at a cost of 50*s* 4*d* in 30 days.[1] It seems unlikely that this could have been done with the much longer millrace at Bedburn Mill. Moreover Harthope Burn might have been the 'Heribourne' from which the watergate (millrace) extended. As late as 1828 this burn was known as the Harehope Burn, and the mill as Hartup Mill, in the same document.[10]

To the west of Harthope Mill are the 'Knotty Hills', overgrown with birch trees. Byrkeknott might possibly have derived its name from these hills, but the fact that the only mention of this name seems to have been in the account roll of Bishop Langley, leads the author to draw the conclusion that the name was given by the bishop to the new bloomery.

North of the Knotty Hills is Hoppyland whence cinders were taken to the bloomery. Hoppyland Hall was at that time rented out to Sir Radulphus Eure,[4] who supplied the bloomery with iron ore from his mines in 'Rayley', 'Hertkeld', and 'Morepytt', near Evenwood, three miles south-east of Bedburn. In 1433 these same mines were farmed out to William Eure at an annual rent of £112 13*s* 4*d*.[11]

The building of the bloomery went on under the personal supervision of John Dalton, ironmaster. The equipment and tools were either made on the spot or bought individually as required. The building was made of timber and roofed with turf. The bloomer made the bloomhearth and the stringhearth and was assisted by another bloomer from a neighbouring bloomery. A carpenter made the waterwheel, gates (sluices), wooden spouts (launders), the bellows, and other necessary wooden instruments.

Among the tools assembled were axes, hammers, rakes, three long iron rods, (all made by a smith in West Auckland), two measures for the ore, scales for weighing the iron, and a sieve for sifting the ore. The ore was brought from mines in Weardale and twelve cartloads of cinders came from a field at Hoppyland.

The carpenter built four huts in four days, and the wood and charcoal were supplied from Bedburn Park. The bloomer as well as the foreman lived on the spot, and their wives helped in breaking and sifting the ore and on occasion worked the bellows.

In the week beginning 17 November 1408, work started and the bloomer tried to smelt the ore. No blooms were produced for the first two weeks, but in the third week the bloomer produced six blooms. From then on about six blooms of iron were produced every week, each bloom weighing 195 lb.

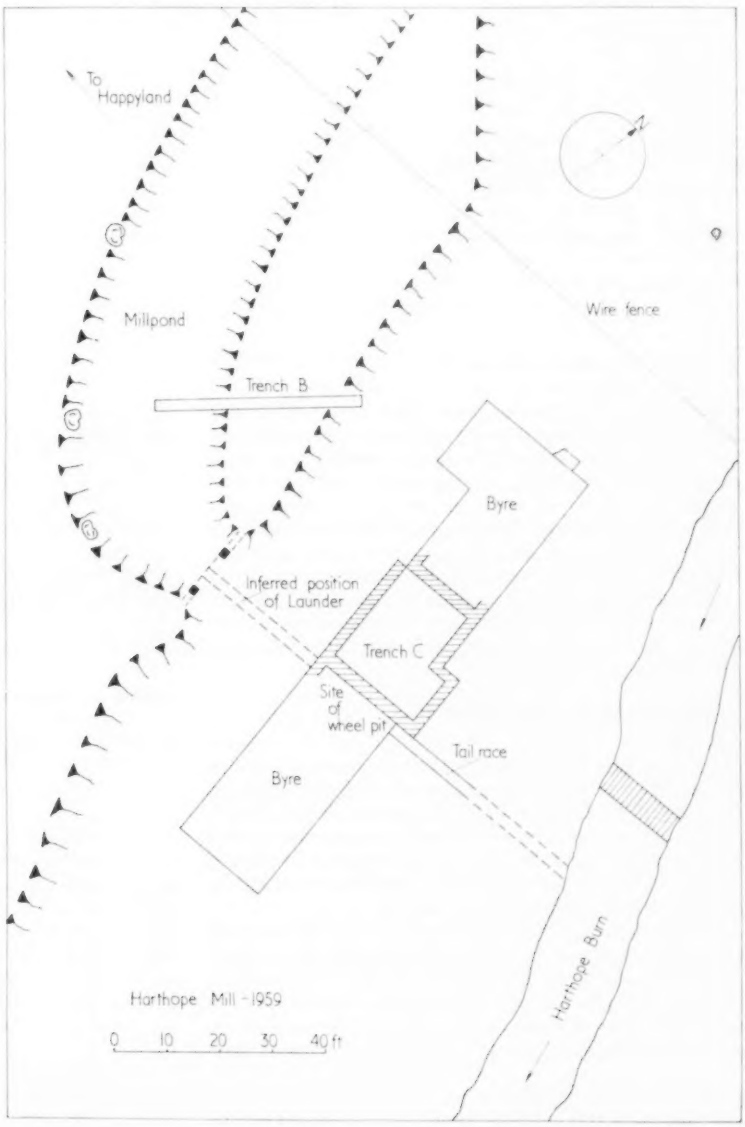
A duodena was the measure for charcoal, and about four duodenae (12·9 tons) were delivered at the beginning of each week; these served both hearths. The measures for ore were fothers and duodenae, one fother representing about 2400 lb. It appears that all the ore (341 tons) was brought at the beginning, since there is no further mention of the delivery of ore throughout the year.

TABLE I Annual input and output

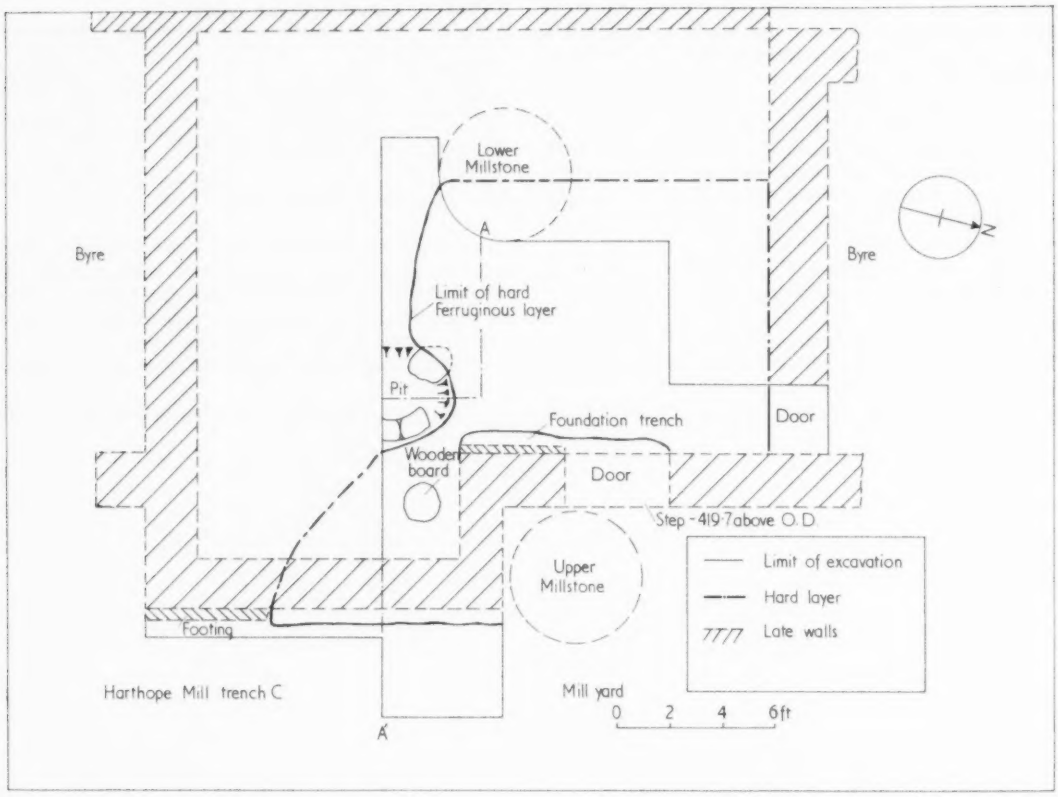
Total ore supplied	341 tons
Total iron produced	24·3 tons
Average output of iron	1200 lb/week
Actual yield of iron (lb Fe/lb Fe in ore)*	16·5%
Charcoal rate for two hearths	12·9 tons/week
Assume ½ for smelting; charcoal rate per lb of Fe	12 lb
Total slag produced (assuming charcoal contains 3% ash)	326 tons

* Based on analysis of nodule given in Table II, col. C

In the first few weeks a few adjustments had to be



2 *Plan of mill, millpond, and excavated areas*



3 *Plan of mill and ferruginous layer*

made. The bellows had to be oiled and a new rope supplied, a tuyere repaired, and a new valve made for the bellows. In July 1409 minor repairs had to be made to the millpond, the gudgeon, and some iron tools.

Wooden trays were used to carry the ore and these were probably made on the spot while a carpenter was available; later they were bought outside.

The quantity of iron produced is given in the roll; this and the calculated charcoal rate, percentage yield of iron, and quantity of slag produced during the year are given in Table I.

EXCAVATIONS AT HARTHOPE MILL

The site

Harthope Mill lies on the right bank of the Harthope Burn, 200 yd before its confluence with the Bedburn (Grid ref. NZ108322–25 in. Durham sheet XXXIII.10).

The mill is set about 40 ft back from the burn itself and is served by a millpond, the bottom of which is 15 ft above the floor of the mill, which in turn is fed by a millrace 100 yd long (Figs.1 and 2).

Examination of the slope behind the mill showed the presence of pieces of slag of primitive type. Since there was no way of knowing whether these had been brought from further afield it was decided to carry out excavations in the area of the mill to try to confirm or reject the suspicion that it was the site of Byrkeknott.

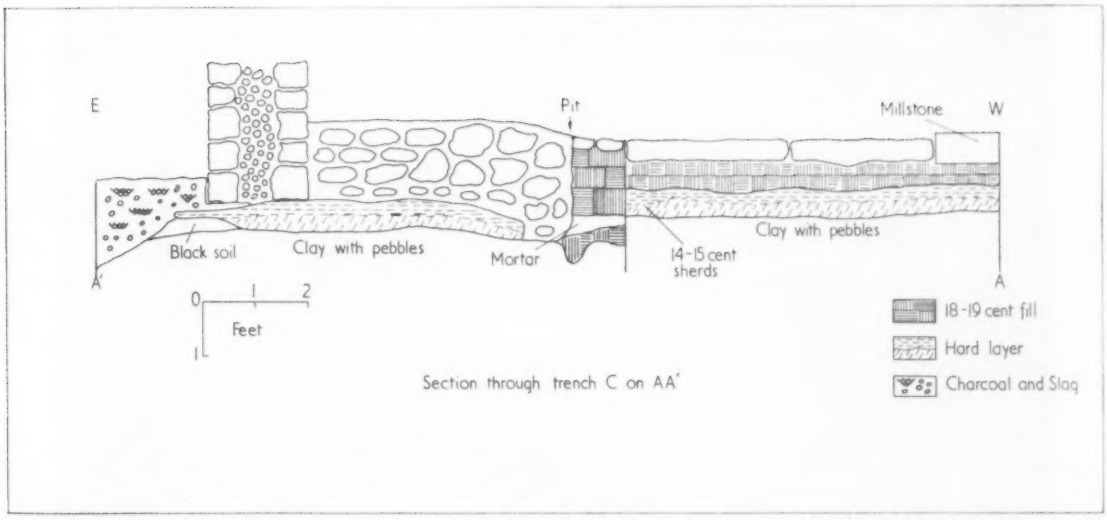
Excavation of the millpond

The account roll gives a great deal of space to the repair of the watergate or millrace, and it was therefore thought that some useful dating evidence might be obtained from a trench cut through the millpond and one of its banks (trench B, Fig.2).

A clay layer formed the bottom of the pond and ran under the east bank for a considerable distance. The clay had been formed naturally because the shelf, on which it had deposited had been part of the old river bed. Under the clay are water-worn pebbles of various types of stone. Presumably the bank was built on the edge of the clay layer to prevent seepage, and well

TABLE II Composition of material from Harthope Mill, wt-%

	A	B	C	D	E	F
	Slag from millpond bank	Slag from ferruginous layer	Partly roasted ore nodule	Compacted fines from roasting (yellow)	Red ore fines from ferruginous layer	Unroasted nodule according to Tomkieff[13]
Fe_2O_3	4·98	2·82	62·48	34·59	31·6	6·71
FeO	38·96	40·97	9·18	1·24	nil	44·05
SiO_2	29·44	32·40	7·60	48·70		8·62
Al_2O_3	9·68	6·90	4·72	2·28		2·89
TiO_2	0·40	0·23	0·05	0·14		0·20
MnO	2·44	6·73	0·88	0·08		...
CaO	5·46	2·80	0·84	2·17		0·94
MgO	4·90	2·70	0·80	0·90		0·77
S	0·14	0·034	0·032	0·021		...
P_2O_5	0·36	0·35	0·22	0·25		...
CO_2	0·33	0·25	6·70	1·94		28·35
Combined H_2O	1·20	1·00	5·60	6·02		4·23
Total	98·29	97·18	99·10	98·33		96·76



4 *Section through ferruginous layer*

away from the edge of the slope to prevent it slipping into the burn.

No dating evidence was found in the bank or the pond, but a considerable number of pieces of primitive slag were found in the bank and the up-cast to the east of it. The composition of this slag is given in Table II, col. A. It would appear that the bank itself was constructed by the tipping of material gathered from the surrounding area after iron smelting operations had been carried out. Since the composition of the slag it contained is no guide to dating, the production of this slag could be synchronous with a Byrkeknott (1408) phase of the site, or related to a possible earlier phase such as that at High Bishopley (12th–13th century).[12] Some potsherds belonging to the earlier period were found in a field 200 yd to the south-west of the site, in conjunction with iron-bearing cinder of primitive type (*see* Fig.1).

The eastern section of the bank, which does not bottom onto clay, consists of sandy material containing slag which is almost certainly material excavated from the actual site of the mill when it was cleared or enlarged.

Excavation of the mill

The central section of the mill is now roofless and derelict, but the miller's house on the north side and buildings on the south side have been converted into byres.

The section excavated had housed the milling machinery, and the bottom millstone appeared to be *in situ* surrounded by the remains of a flagged floor. This floor was removed exposing a layer which was obviously 18th–19th-century fill. It consisted of black earth containing coal, numerous potsherds, pieces of iron, a 1-lb lead weight, a cast-iron weight, and a few iron candlesticks. It appeared that this material had been put down to level the floor before placing the flags in its last phase.

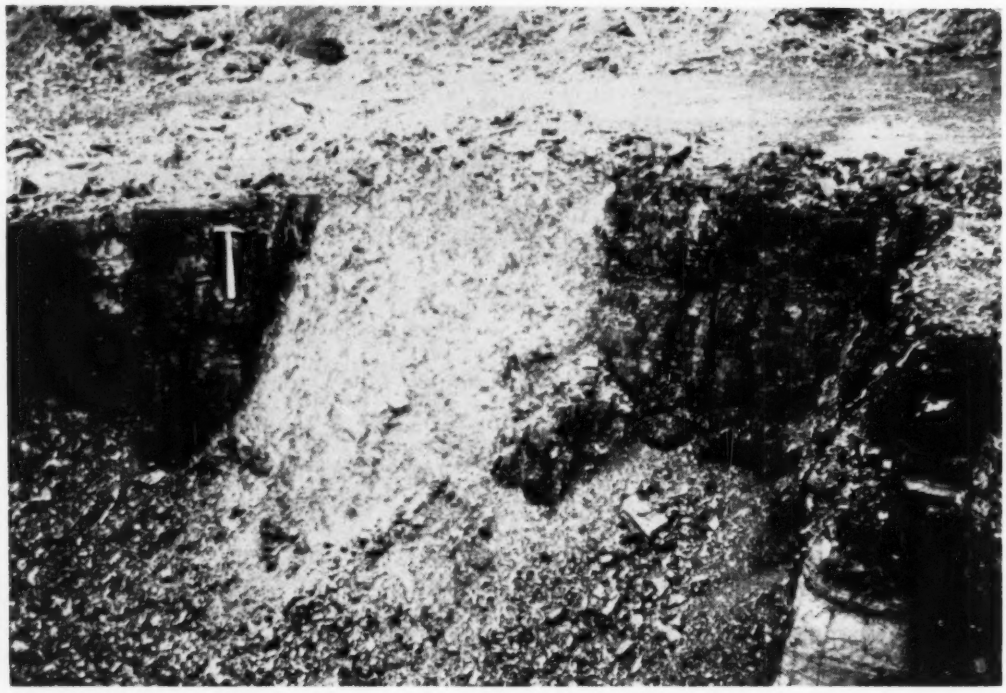
Under this layer was a hard, highly ferruginous layer varying from 2 to 7 in. thick; below was natural clay, now stained or burned red, with a pebbly subsoil beneath. This ferruginous layer covered an area roughly 17 ft × 15 ft (Fig.3) but originally it may have been larger. The hard ferruginous layer contained a considerable amount of slag, charcoal, iron-ore nodules, and fines. On the east side it had been cut through in some places by the foundation trench of the mill-wall; but some parts of this wall had been built direct on to the hard layer (Fig.4).

Metallurgical finds

The slag was of a somewhat different kind physically from that found on primitive smelting sites of Roman or early medieval date. The porosity was much finer and more widespread, giving it a honeycomb texture. The upper surface was smooth and typical of a tapped slag. As seen from the composition given in Table II, col. B, this slag has a slightly higher silica content than the slag found in the bank, and it suggests a higher temperature and a more powerful blast; but it is still a high iron-containing slag typical of the primitive or direct smelting process.

The Byrkeknott account roll[3] refers to the use of '*sindres a dicto campo de Hopyland . . . pro ferro novo ibidem cum ejusdem temperando*'. The suggestion here is that slag was carried from the field of Hoppyland nearby to modify the iron produced in the new bloomery. The slag or cinders used could have been those produced by earlier ironworkers in the area, as suggested, but their purpose is not certain. One possibility is suggested by the respective analyses of slag (Table II, col. B) and ore (col. C). The ore is comparatively low in silica and manganese oxide content, while the slag from the same ferruginous layer is high in both. Even allowing for such a high yield of iron as 20%, it is difficult to see why the manganese content of the slag should be so high, unless additional material high in manganese has been added. As shown in an earlier paper[12] the manganese oxide content of the local bog ores can be as high as 15·5% giving slags containing 13% of manganese oxide.

If an appreciable amount of such slag was charged with the ore shown in Table II, col. C, a slag containing



5 *View of filled bell-pit going through coal, exposed by open-cast working* (scale: hammer = 1 ft long)

the percentage of manganese oxide in col. B could result. The main function of the fayalite-type slags found in this process is to remove the gangue at a normal working temperature of about 1200°C. The lime content of the ore is low and added lime would not be dissolved by the slag at such a low temperature. Thus the only way of reducing the amount of iron lost in the slag would be to add slag relatively low in silica, which would act as a flux and absorb some additional silica if the working conditions were correct. It is suggested that by working at temperatures somewhat higher than the minimum of 1150°C, and using strongly reducing conditions, the earlier low-silica slags could have their silica contents increased from 20 to 30%.

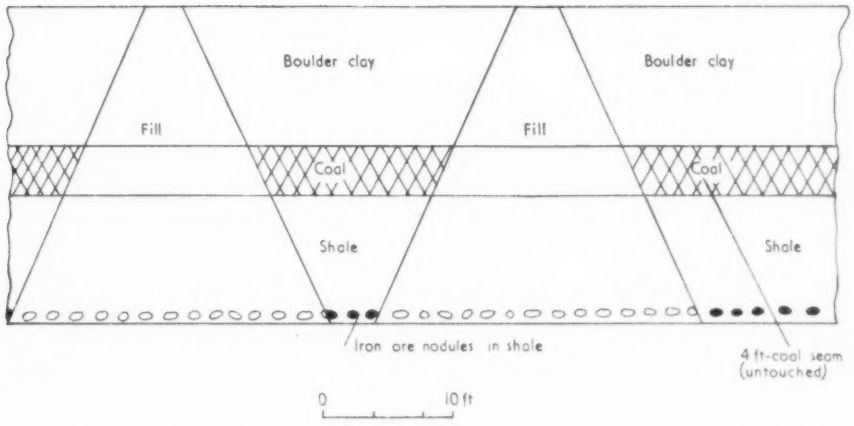
A microexamination of a piece of slag from the ferruginous layer showed it to consist of laths or plates of fayalite in a glassy matrix (probably a melt of tridymite and fayalite). There were also some small particles of metallic iron and some magnetite dendrites. The smaller holes seemed to be filled with a dark phase which was probably hematite or limonite.

Various forms of iron-oxide-containing material were found. The most important was argillaceous nodular iron ore which probably came from bell-pits in the Evenwood area to the south of the site, which is the area mentioned in the account roll. Some of the nodules had been roasted, others were as mined (*see* Table II, col. C for composition).

At the time of this excavation (April 1959), an open-cast coal excavation was being carried out at Rowntree Farm, near Evenwood (grid ref. NZ118285), which exposed some bell-pits. It is clear that these had been worked for iron, as the workings had gone right through the coal to the nodular ore beds below, and no attempt had been made to remove more than the necessary coal to allow access to the ore beds. Part of one of these pits is shown in Fig.5 and their disposition is shown diagrammatically in Fig.6. They are of typical medieval type. The formation and occurrence of nodular ores in the coal measures has been discussed by Tomkieff.[13]

Some of the ferruginous material found in the hard layer consisted of fines of lower iron content than the nodules (Table II). This material probably came from the surface of the nodules after roasting; the surface layer, according to Tomkieff, being rather poorer in iron than the interior. A lump of hard sandy material was also found, which at first sight looked natural. It contained, however, small pieces of coal ($\frac{1}{4}$-in. cubes) and some wood, and appears to have been low grade ore or fines compacted during roasting (*see* Table II, col. D for composition).

Some doubts are often expressed as to the impossibility of using coal in the direct process, since although the pickup of sulphur from coke in the modern blast furnace process is relatively high, in the direct process with lower temperatures and iron in the solid state, the pickup of sulphur might be expected to be much lower. Also coal coke is often used for fuel in the smithing hearth. For this reason it is worth mentioning that in tests carried out in this department on pure iron in contact with molten iron sulphide at 1000°C for 24 h, the pickup was found to be high enough to produce continuous intergranular films of iron sulphide which could destroy the properties of the metal. With porous reduced ore at 1250°C, pickup of sulphur would be expected to be easier and the use of coal for the smelting process, as opposed to the roasting process, is out of the question. It would not be expected



6 *Section through bell-pits showing depth of coal and nodular ore in shale*

that the presence of sulphur under the oxidizing conditions of roasting would be deleterious, nor of course is it deleterious in smithing when the metal is in the massive state for only a short time in relatively oxidizing conditions. Further work on this aspect of primitive smelting is obviously required.

It is debatable whether the shortage of charcoal was the cause of the final demise of the site as an iron smelting works. Perhaps towards the end unsuccessful experiments were made on the use of coal instead of charcoal.

Charcoal

Charcoal from the ferruginous layer was made from a wide range of trees. Seventy-four per cent was made from birch wood, 14% from poplar or willow, 8% from hazel, and 4% from maple. No charcoal was made from beech wood and oak was also entirely absent, which is in marked contrast to High Bishopley where 90% of the charcoal was from oak wood.[12]

Pottery

The only potsherds found on this site that were well stratified were in the hard ferruginous layer and consisted of a reddish-grey ware with a green glaze on the outside, which were dated as 14th–15th century. One piece was a rim, which suggested a flagon-type vessel with a rim of about 5 in. dia. A roughly circular piece of birch wood, 12 in. dia., $\frac{3}{4}$ in. thick with the grain running in the direction of the diameter was found embedded in the upper surface of the hard layer, and might have been a platter.

Hearths

Unfortunately no direct evidence of a hearth was found. It would be expected that at this time the smelting hearths would be of the Catalan type sunk into the ground as shown in Fig.7. They could have been raised on stone platforms as shown by Agricola as being in use in Germany about 1550.[14]

The only suggestion of a hearth was the dip in the hard floor on the south side (Fig.3) which contained stones on which the hard layer had been deposited. As the remains of a hearth at this point would probably have made levelling difficult in the reconstruction of the 18th century they might have been removed together with any residual cinder.

The hearth would have to be large enough to produce blooms weighing about 200 lb, the order of size normal for the 15th century and mentioned in the account roll relating to Byrkeknott. Agricola's hearths were only 18 in. dia. and were capable of producing blooms weighing 2–3 cwt from a rich ore.[14] Percy gives much the same dimensions for the square Catalan hearth in use for similar sized blooms in the 18th century.[15]

The roll mentions the existence of two hearths, the bloomhearth and the stringhearth. It would seem to be impossible for the area excavated to contain more than one hearth. It seems more probable that the other hearth was to the south of the wheelpit (*see* Fig.2) giving a more or less symmetrical arrangement. The absence of hammer scale in the area excavated strongly suggests that it contained the bloomhearth, and not the stringhearth where scale would be expected. Hammer scale (Fe_3O_4) has recently been found by the author in a Roman site in Norfolk and appears to be capable of remaining unchanged for over 1600 years.

Bellows

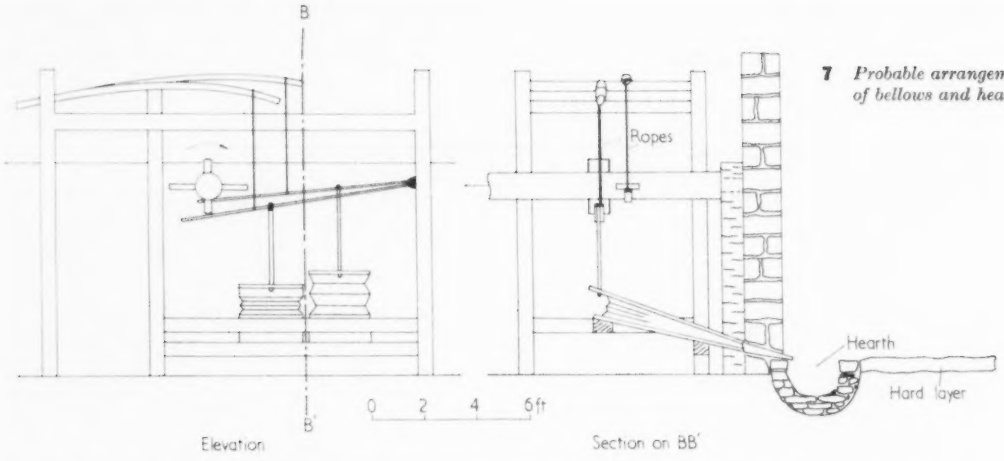
The roll refers to the use of a rope and a swordblade in conjunction with the bellows. The position of the working floor in relation to the wheel-pit, the height of the shaft above floor level, and the probable position of the hearth, suggest an arrangement as shown in Fig.7, where the bellows are in line with the axletree and driven by cams by means of a lever system using ropes and push rods, together with saplings as return springs.

Individual details of the mechanism would be well known to the people of the time, and the method would permit hand working if the water supply proved insufficient.

CONCLUSIONS

The following considerations provide sufficient circumstantial evidence to associate this site with the Byrkeknott of the account roll:

1. It is close to Hoppyland and takes its water from the Harthope Burn which can be equated with 'Heribourne'. It lies a short way back from the burn in a position which is almost unique on that river. The millrace is a reasonable length (only 100 yd) unlike



7 *Probable arrangement of bellows and hearth*

that of Bedburn Mill which is ½-mile long and which would appear to be a much more difficult undertaking for a comparatively early period. In spite of this Harthope Mill provided a head of 15 ft, and therefore would be an obvious first choice, if available, for conversion. It is still 'juxta Bedbourne', being only 200 yd from that river.

2. It contains a hard ferruginous working floor consisting of the elements of primitive iron smelting, i.e. charcoal, ore, and slag.

3. The floor contains well stratified pottery belonging to the 14th–15th centuries.

The ore used at Harthope Mill was an argillaceous carbonate ore in nodular form, probably from the neighbouring coal measures. The charcoal was mostly birch, and the slag was a typical primitive type consisting mainly of fayalite.

The head of water available was 15 ft, and for most of the year the quantity should have been sufficient to keep two hearths going continuously.

ACKNOWLEDGMENTS

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Changes occurring in the surfaces of mild-steel specimens during fatigue stressing

G. F. Modlen, M.A., Ph.D., and G. C. Smith, M.A.

SYNOPSIS

Evidence is presented from work upon the effects of surface removal and of intermediate annealing, in support of the idea that microcracks form early in fatigue, and that removal of these cracks removes all that may be called fatigue damage. Metallographic observations are consistent with this view. 1718

INTRODUCTION

IT HAS LONG BEEN RECOGNIZED that fatigue damage takes place by a gradual process and is not confined to the last portion of the test. In this work, corroborative evidence that this damage is associated with surface cracks propagating into the material rather than with any form of work-hardening, has been obtained in four ways. If cracks are present only in the surface of a specimen, then test-pieces machined from the interior of fatigued specimens should be unimpaired in their resistance to subsequent fatigue stressing. Similarly, interrupting a test to remove the surface, by grinding or by some other means, should make it possible to prolong the test indefinitely. Intermediate annealing may be expected to have little effect upon subsequent resistance to fatigue stressing, since microcracks, rather than any form of work-hardening, are thought to constitute fatigue damage, and these would remain unchanged under this treatment. Lastly, metallographic evidence has been obtained for the existence of cracks in the first 10% of the fatigue life.

PREFATIGUED SPECIMENS

The British Welding Research Association made available test pieces of $1\frac{1}{4}$-in. mild steel plate which had been fractured in a 100-ton pulsator in repeated tension. The composition of the steel, wt-%, is as follows:

C	Si	Mn	P	S	N_2
0·15	0·06	0·57	0·024	0·03	0·005

Magnetic crack detection showed that although a number of superficial cracks were present in these specimens, no new cracks could be exposed by grinding away successive surface layers. From the 100-ton specimens it was possible to machine six specimens for testing in a 6-ton Losenhausen pulsator. Figure 1 shows approximately the positions from which the 6-ton specimens were obtained, as well as a drawing of the smaller specimens. Much distortion took place around the final fracture of the 100-ton specimens, but hardness traverses showed that the test sections of the small specimens were unaffected by this. Fatigue tests were carried out in repeated tension. In the machine used, a tensile load is applied by compression of a spring, and the appropriate load range is obtained by opposing this tensile load by a fluctuating compression load which is obtained hydraulically. Since deformation of the specimen causes a change in the tensile load exerted by the spring (that is, a change in mean load), in the tests reported here, the maximum load was applied statically by compressing the spring, and the initial elongation (if any) of the specimen was taken up. Once the test had been started, no further adjustment was made to the spring load.

The S/N curves obtained from the fatigued material were compared with that obtained from specimens machined from the gripped portions of the 100-ton specimens. The fatigue limit obtained from the original tests in the 100-ton machine was 13 tons/in^2, as compared with 22 tons/in^2 obtained from tests in the 6-ton machine. This difference may be due mainly to differences in surface finish, the large specimens retaining the as-rolled surface, whereas the smaller specimens were taken down to 00 emery. Machine differences may also be important, but this does not invalidate the comparison between pre-fatigued and as-received material, since the curves for comparison were obtained on one machine using the specimen of Fig.1. The results are shown in Fig.2. The mechanical properties, as estimated from tests upon Hounsfield tensometer specimens of 1/40 in^2 cross-section, are as shown in Table I. It can be seen that the S/N curves are consistent with these mechanical properties, and that the prior fatigue stressing has given rise to no deleterious effects.

INFLUENCE OF SURFACE REMOVAL

Fatigue tests were interrupted so that the specimen surfaces might be removed either by grinding or by electropolishing. Before testing, the specimens were given a prolonged electropolish, so that no adventitious effects might arise from changes in surface condition. The results of these tests are summarized in Fig.3, in which the course of each test is shown. It is clear that the depth removed each time the test is interrupted must exceed a critical value for there to be any increase in total life fracture.

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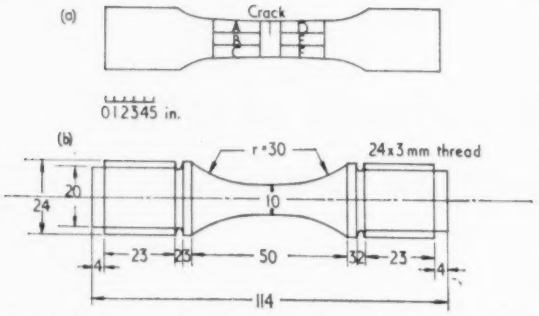
Dr Modlen, who is with the Department of Metallurgy, Sheffield University, was formerly of the Department of Metallurgy, Cambridge University. Mr Smith is with the Department of Metallurgy, Cambridge University.



1 (a) *100-ton specimen showing approximate positions from which 6-ton specimens were machined* (b) *Fatigue specimen for 6-ton machine (dimensions in mm)*

In the second series of tests, only one surface removal was carried out, the specimen thereafter being tested to fracture. In Fig.4 are shown the total number of cycles to fracture as a function of the depth removed; three sets of specimens have been tested, corresponding to interruptions after 200000, 300000, and 400000 cycles. Each point in the figure corresponds to one test piece. It is seen that in an interrupted test, the total number of cycles to failure is greater than in an uninterrupted test, provided the depth removed is greater than a critical value, this critical value increasing with the number of cycles that has elapsed before interruption of the test.

If the test is interrupted after a large number of cycles then the results become irregular because of the usual scatter in fatigue lives. Of two specimens run to 500000 cycles, one, after a reduction in diameter of 0·064 in. broke after a total of $5{\cdot}65 \times 10^5$ cycles: another after a reduction of 0·050 in. remained unbroken after a total of 10^7 cycles. In this second specimen, a crack was observed, and its removal by prolonged electropolishing was followed. The crack was found to be approximately semicircular, with a diameter of 0·043 in. In this case, at least, the removal of the fatigue crack may be equated with the removal of fatigue damage.

TABLE I Mechanical properties of specimens $\frac{1}{40}$ in² cross-section

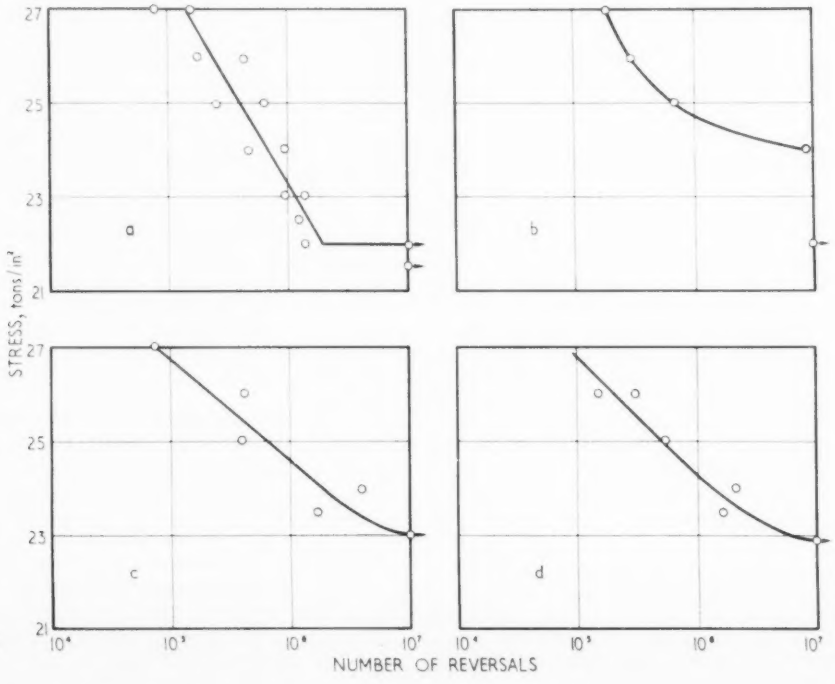
Fatigue treatment	Yield point, tons/in²	UTS tons/in²	Elongation, %
(a) None	14	28·3	35
(b) 0–20 tons/in² 112800 cycles	28	34	20
(c) 0–18 tons/in² 586400 cycles	25	31·5	25
(d) 0–14 tons/in² 2×10^6 cycles	24	30·6	25

INTERMEDIATE ANNEALING

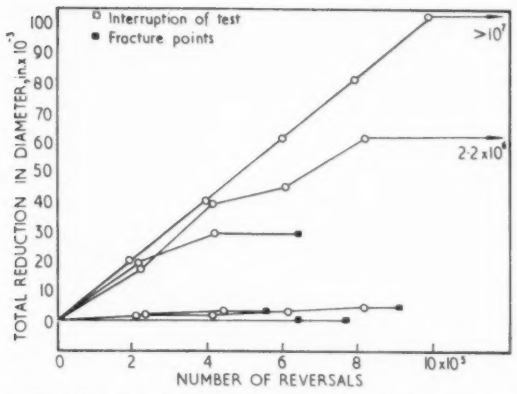
Interrupting a fatigue test to resoften the specimen should have little influence on the total life to fracture, if fatigue damage is associated with microcracks rather than with work-hardening. The results shown in Table II indicate that this is indeed true: statistical analysis shows that the difference between the means of the two groups is not significant at the 5% level. Metallographic examination showed that the same system of deformation lines persisted throughout a test.

METALLOGRAPHIC WORK

Chevenard microtorsion test pieces having a test-section 1·5 mm dia. and 1 cm long were machined from the $1\frac{1}{4}$-in. plate in various orientations. The specimens were electropolished before test. Specimens having their axes parallel to the direction of rolling, and those having axes parallel to the plane of the plate and at 45° to the direction of rolling, had the same S/N curve



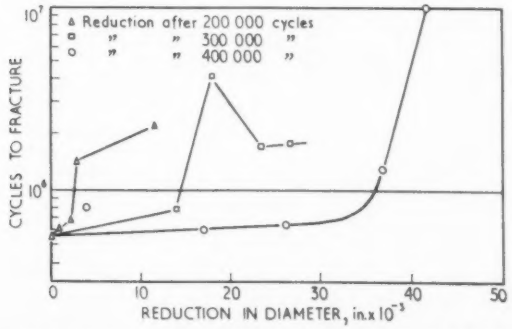
2 *S/N curves for virgin and for prefatigued material (details of pretreatments are given in Table I)*



3 *Results of tests interrupted for successive surface removals. The points showing total reduction in diameter following each interruption have been joined: also shown are two specimens run straight through to fracture (Repeated tension, 0–23 tons/in²)*

with a fatigue limit of $\pm 8{\cdot}6$ tons/in². Specimens having axes parallel to the plane of the plate, but transverse to the direction of rolling, or axes at right-angles to the plane of the plate, gave another S/N curve with a fatigue limit of $\pm 7{\cdot}7$ tons/in². A comparable difference was found in repeated tension between transverse and longitudinal specimens, having fatigue limits of 21 and 22 tons/in² respectively. Under the microscope it was seen that cracks in microtorsion specimens belonging to the lower S/N curve invariably grew from inclusions elongated at right angles to the specimen axis (Fig.5). The final fracture was flat and at right angles to the axis. In the other group cracks did not always start from inclusions, and the final fractures were jagged. This indicates that it is the presence of inclusions elongated in the direction of rolling, rather than some other anisotropic property of the plate such as banding, which is responsible for the observed anisotropy of fatigue behaviour. The behaviour of inclusions under repeated torsion is similar to some observations of Duce[1] upon free-cutting steel. The other metallographic features seen resemble those found by other workers.[2–4]

To demonstrate the early formation of microcracks, a microtorsion specimen having inclusions elongated parallel to its axis was fatigued at a strain setting which would cause fracture after $1{\cdot}5 \times 10^6$ cycles. The test was interrupted after 10^5 cycles, and the specimen



4 *Total number of cycles to fracture as a function of the reduction in diameter (Repeated tension, 0–23 tons/in²)*

TABLE II Influence of resoftening on specimens of mild steel fatigued at ± 13 tons/in²

	No. of cycles to failure, × 10³
Uninterrupted test	600·4, 486·3, 432·4, 374·6, 351·6, 298·3, 279·2, 173·8
Tests interrupted every 100 000 cycles. Vacuum anneal 1 h at 650°C	387·9, 311·7, 303·6, 279·5, 247·0, 178·8, 175·7

mechanically polished and lightly etched (Fig.6). It can be seen that segments of deformation markings have persisted under this treatment, and on further fatigue have developed into definite cracks. It is thus possible to identify microcracks within the first 10% of the fatigue test.

Two further metallographic observations of interest relate to slip band extrusion and to microcrack formation under repeated compression loading. The specimen and steel used are given in ref.5.

No extrusion had been found in tests upon as-received material, but marked extrusion was observed in tests upon cold worked material (Fig.7). Microcracks were also found under repeated compression loading (Fig.8). These microcracks could be found in diametrically opposite positions on the surface of the specimen. Thus it is unlikely that tensile stresses introduced by a possible slight buckling of the specimen could be responsible for them.

DISCUSSION

Frost[6] has reported some work involving the testing of specimens machined from a large test piece fatigued in tension-compression. The material used was an aluminium alloy, and in this material very little difference was observed between virgin and prefatigued specimens. In the steel of the present investigation, it is probable that strain-ageing contributes to the improved fatigue resistance of the prefatigued material. It is true to say, however, that repeated stressing does not render the interior of the specimen more susceptible to fracture under subsequent fatigue testing.

Results similar to those obtained by other workers have been obtained from the tests which were interrupted a number of times to remove successive surface layers.[7–13] Siebel and Stähli[8] in a series of experiments in rotating bending, interrupted each test once to carry out a constant reduction in diameter. By using a number of test pieces a curve was constructed relating the percentage increase in total life to the number of cycles which had elapsed before the test was interrupted. They found that the reduction in diameter was ineffective in increasing the total number of cycles to fracture, if it was carried out early in the test. Carried out later in the test, the reduction in diameter did result in an increase in the life of the specimen, but at still later stages the treatment again became ineffective. Siebel and Stähli explained these three stages in the following way. At first, there are no microcracks present, and hence removing the surface is ineffective. After microcracks have formed, removing them results in an increase in the total number of cycles to failure: but when the depth of the cracks exceeds the surface depth removed, then the treatment becomes ineffective. However, if the increase in total life caused by a surface removal after x% of the

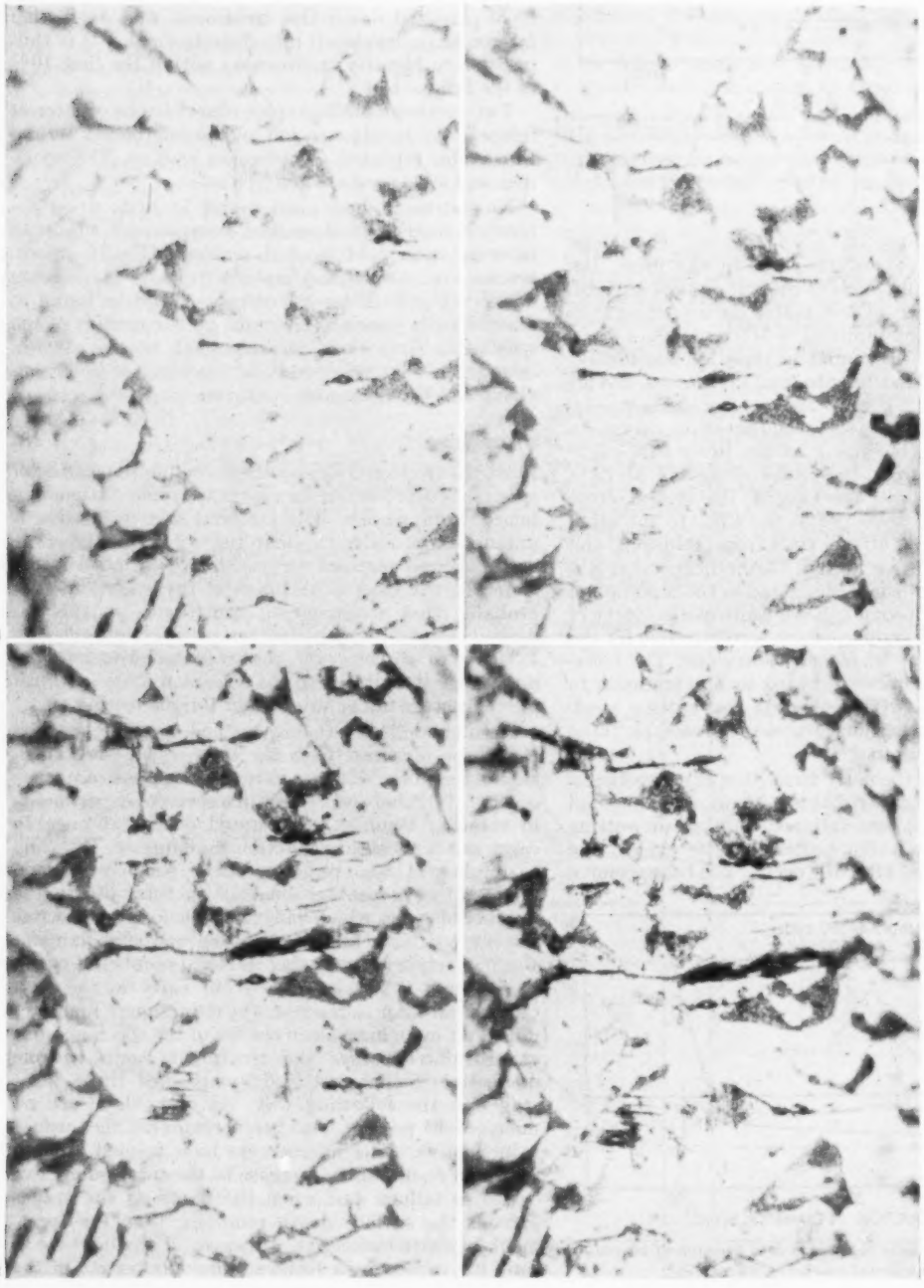
expected life is about $x\%$, then for small x it would be difficult to be certain that this increase had indeed occurred. Thus Siebel and Stähli's conclusion that fatigue cracks were not present early in the test may not be justified.

The experiments making use of intermediate annealing confirm work upon brass,[15] nickel,[14] and aluminium.[10] Although the difference between the means of the two groups of specimens is barely significant, the lower lives of test pieces annealed at an intermediate stage may be due to the ability of microcracks to propagate more rapidly in the re-softened matrix than in the fatigue-hardened matrix.

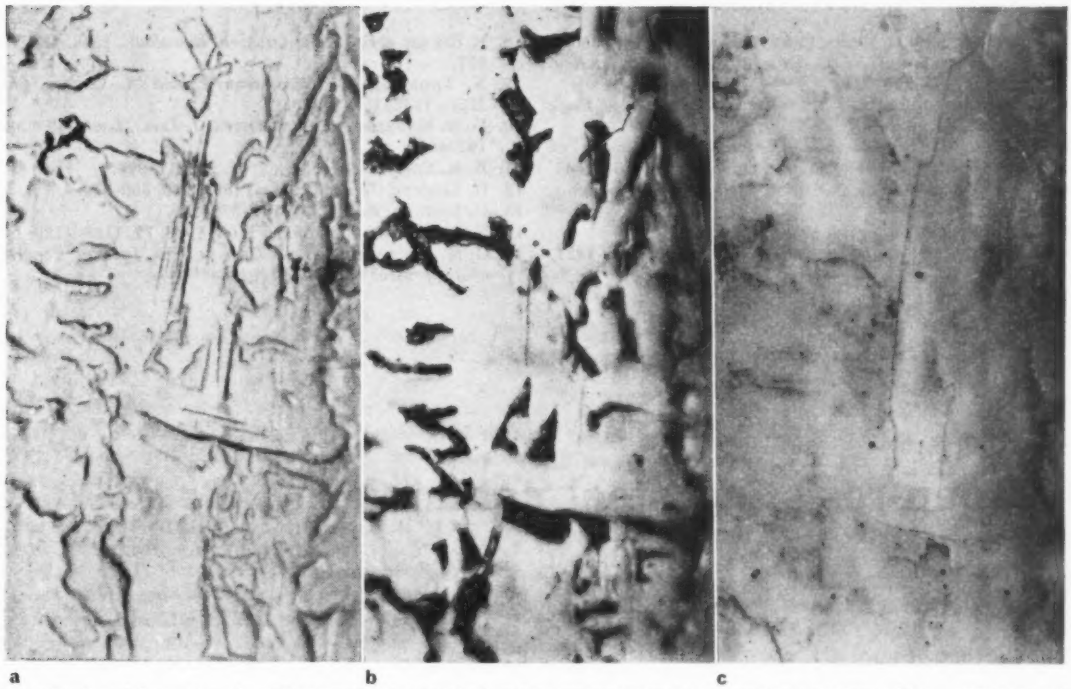
The metallographic work indicates that the sites of eventual cracks may be identified after the first 10% of the fatigue test.

CONCLUSIONS

1. It has been demonstrated that the interiors of specimens subjected to fatigue do not suffer damage with respect to subsequent fatigue testing.
2. It is possible to prolong the endurance of test



5 *Deformation about an inclusion. Alternating torsion. Fracture occurred after 252 000 cycles;*
(a) *after 10 000 cycles;*
(b) *after 20 000 cycles;*
(c) *after 100 000 cycles;*
(d) *after 250 000 cycles*
×250



6 (a) *Surface deformation after 100 000 cycles* (b) *As* (a) *after light mechanical polishing and light etching* (c) *After 1 000 000 cycles, followed by repolishing and light etching* ×250

pieces by removing the surface layers to which cracking is confined, and the depth that has to be removed after a certain number of cycles to produce this effect increases as the number of cycles increases.

3. Resoftening is not effective in eliminating the deleterious effects of fatigue stressing.

4. Metallographic examinations have shown that persistent slip lines may be found in mild steel. Evidence is also presented for the existence of persistent slip bands under repeated compression loading.

ACKNOWLEDGMENTS

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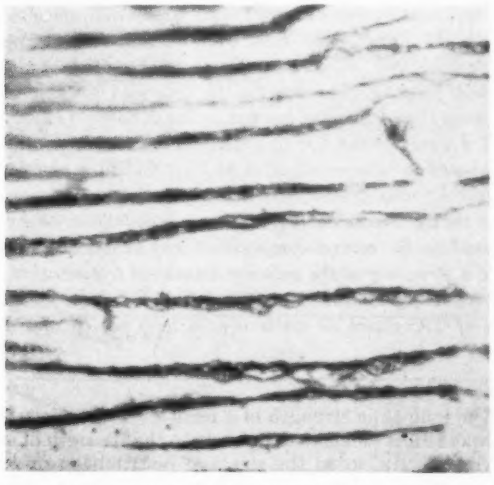
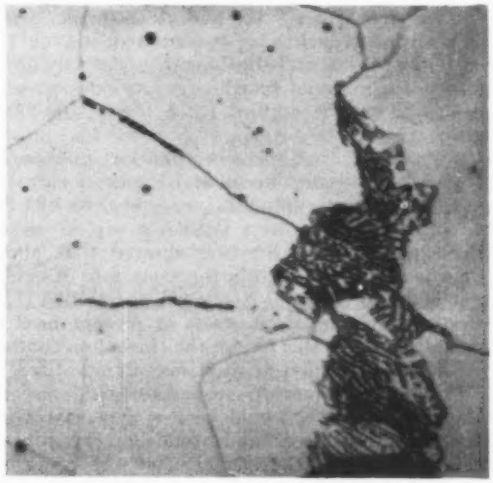


7 *Slip band extrusion. The specimen had been strain-aged to 155 VPN before testing at ±15·5 tons/in. The micrograph shows the deformation after fracture which took place in 45 600 cycles* ×2000



8 *A persistent slip band observed in repeated compression loading at a nominal stress of 0–25 tons/in. After 950 000 cycles the specimen was repolished and lightly etched* ×1000

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A creep-resisting steel containing 7%Cr

G. A. Mellor and S. M. Barker

INTRODUCTION

GREATER EFFICIENCY in the generation of electric power from steam turbines can be attained when higher steam temperatures and pressures are employed. The designers of steam power plant therefore need materials that are resistant to creep and to oxidation at elevated temperatures. Hitherto for steam pipes and superheater tubes ferritic materials have been adequate for steam temperatures up to 1050°F (566°C) but in many cases still higher temperatures have demanded the use of austenitic alloys. Ferritic steels have many advantages over austenitic steels, e.g. lower cost, lower thermal expansion, and higher thermal conductivity. It would therefore be very desirable to have ferritic materials with good resistance to creep and oxidation in the temperature range 600–650°C. In superheater tubes and steam pipes, where the highest temperatures are encountered, to avoid the use of unduly thick-walled tubing it is generally desirable to use a material to which a working stress of 2–3 tons/in² can be applied for a life of 100000 h or more.

It is known[1, 2] that there is a marked increase in resistance to oxidation in air and steam at elevated temperatures when chromium was added to a C–Mo steel. An investigation by a BISRA group on scaling of steels at high temperatures showed that about 7%Cr was required to attain the same rate of oxidation at 600–650°C as was displayed at 525–575°C by the ferritic creep-resistant steels at present used in power stations. For this reason the chromium content of the steels to be investigated was standardized at 7%. Provided good creep properties could also be obtained such a steel would be less expensive than existing 12–13%Cr steels and would be very suitable for use in the range 600–650°C.

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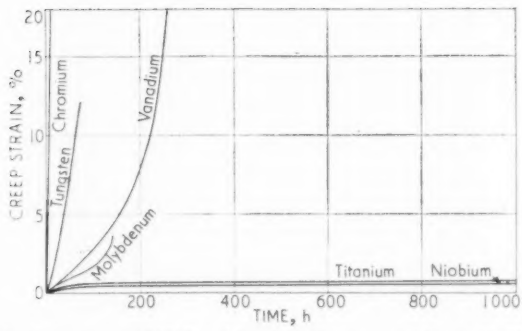
The authors are at the National Physical Laboratory, Teddington.

SYNOPSIS

The work described began as a result of the lack of a ferritic steel suitable for service in the temperature range 600–650°C, with particular reference to superheater tubes in which resistance to creep and oxidation is important. In steels containing chromium, molybdenum, and vanadium, which have been adequate for temperatures of 1050°F (566°C), an increase of chromium content reduces scaling but makes the steel weaker in creep. The task undertaken was to improve the creep resistance of steel containing about 7%Cr. After making a number of steels from pure materials it was found that additions of molybdenum and titanium improved the strength at 650°C to a marked degree. An optimum composition and the best heat-treatment were found, using vacuum-melted steels. An ingot of the same composition was cast in a steelworks and made into a superheater tube by the normal processes. As expected, the tube was much weaker in creep than hot-rolled bar but in test at 650°C (1249°F) and 5 tons/in² the life to rupture was 476 h, which is estimated to be equivalent to at least 63000 h at 621°C (1150°F) and 3 tons/in². Scaling resistance increases with the chromium content while creep resistance seems to depend on the correct composition and heat-treatment to give a structure at the solution-treatment temperature of α+γ+TiC and at the service temperature a fine precipitate of TiC which is stable over a long period of time.

1771

The long-time strength of a ferritic steel at elevated temperatures seems to depend upon the strength of the ferrite matrix, upon the size and distribution of any other phase, and upon the lack of deterioration of the structure over a long period of time at the testing or service temperature. Austin, St John, and Lindsay[3] showed that the strength of ferrite at temperatures up



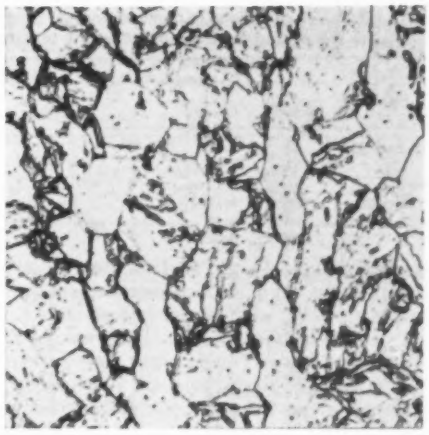
1 *Creep tests at 650°C and 2 tons/in² in vacuo on iron with 1% addition*

to 538°C was increased by various elements in solution, namely molybdenum, chromium, manganese, and silicon. When carbon is present many elements form carbides such as Cr_7C_3, $Cr_{23}C_6$, Mo_2C, V_4C_3, TiC, and NbC and it seems that creep resistance is increased when the carbide particles are very small and when they do not grow or coalesce to any marked extent during service at elevated temperatures.

Crafts and Lamont[4, 5] investigated the form of the carbide found in 5%Cr steels containing molybdenum and vanadium and showed that for the best properties at elevated temperatures particles of the stable carbide V_4C_3 should be present in preference to chromium carbides. Colbeck and Rait[6], and Ward and Rait[7] studied the creep behaviour of 3%Cr steel containing molybdenum, tungsten, and vanadium with variations in composition and heat-treatment. They concluded that molybdenum and tungsten in solution in the ferrite made notable contributions to creep strength, while the vanadium formed finely divided V_4C_3 which resisted growth and coalescence and exerted a beneficial influence on the creep resistance. On increasing the chromium content they found that V_4C_3 was replaced by Cr_7C_3, a coarser carbide subject to growth at 650°C and offering little resistance to creep. There was in fact a continuous fall in creep strength with increasing chromium from 1% to 8%.

Other investigators[8–11] have studied the effect of carbide-forming elements on steel containing chromium. It may be concluded from the diagrams published by Simmons and Cross[12] that the 100000 h rupture stresses of the steels containing over 5%Cr are approximately:

	tons/in²
at 1100°F (593°C)	1·8–2·7
1150°F (621°C)	1·3–2·1
1200°F (649°C)	0·9–1·4



2 *Steel 112, heat-treated 15 min at 1150°C, water-quenched and tempered 1 h at 750°C* ×500

These steels could therefore not be used in power stations at 600–650°C with working stresses above 1 ton/in² and this is scarcely enough. In the work described in the present paper the objective of a working stress of 2–3 tons/in² at 1150°F (621°C), if achieved, would enable ferritic steels to be used in power stations at temperatures far enough in advance of present working temperatures to be worth while, and it is not so far ahead of the properties obtainable in existing Cr–Mo steels as to seem unattainable.

EXPERIMENTAL WORK

Preparation of steels

For most of the work, steels were made from fairly pure materials so that the results of tests would not be confused by the presence of too many variables. Use was made of a 25-lb capacity vacuum-melting furnace previously described by Hopkins, Jenkins, and Stone.[13] Swedish ingot iron, chromium, and molybdenum were melted together *in vacuo*, and in an atmosphere of hydrogen at atmospheric pressure circulating for 2 h to remove oxygen. No final additions of deoxidant were necessary to secure sound ingots and the steels were therefore free from the silicon and manganese normally found in commercial steels. Alloying additions were made just before pouring under a reduced pressure of hydrogen. Ingots were cropped and rolled to $\frac{5}{8}$ in. dia. for machining into creep test-pieces. Silicon and manganese were added to five vacuum-melted steels to bring them more into line with those made commercially. Chemical analyses are given in the Appendix.

TABLE I Effect of carbide-forming elements on the creep behaviour of 7%Cr steel at 650°C and 2 tons/in²

Steel	Composition, % C	Cr	Mo	Addition	Heat-treatment	Creep strain, % At 200 h	At 300 h	At 500 h
30	0·15	6·98	1·00	0·50 Zr	15 min 1150°C, WQ	0·322	0·375	0·455
42	0·15	7·02	1·87	0·49 V	15 min 1150°C, WQ + 16 h 750°C	0·212	0·233	0·29
39	0·15	6·89	0·90	0·51 Nb	15 min 1150°C, WQ	0·25	…	…
39	0·15	6·89	0·90	0·51 Nb	15 min 1150°C, WQ + 1 h 750°C	0·118	0·142	0·180
39	0·15	6·89	0·90	0·51 Nb	15 min 1150°C, WQ + 16 h 750°C	0·178	0·21	0·26
39	0·15	6·89	0·90	0·51 Nb	15 min 1150°C, WQ + 48 h 750°C	0·306	…	…
40	0·14	6·97	1·89	1·06 Nb	15 min 1150°C, WQ + 16 h 750°C	0·075	0·092	0·119
35	0·15	6·86	1·00	0·52 Ti	15 min 1150°C, WQ + 16 h 750°C	0·026	0·026	0·026
43	0·15	6·94	2·11	0·54 Ti	15 min 1150°C, WQ + 16 h 750°C	0·026	0·027	…

WQ water-quenched.

TABLE II Effect of variations in compositions of titanium-bearing steels, heat-treated 15 min, 1 150°C, water-quenched + 1 h at 750°C, and tested at 650°C and 5 tons/in²

Class	Steel	Composition, % C	Cr	Mo	Ti	Creep strain, % At 200 h	At 1 000 h	At 2 000 h	Duration of test, h	Elongation at rupture % on 2 in.
Very low carbon	44	0·006	6	1	0·5	1·5 at 50 h	...	...	TS 97	...
	94	0·05	7	1	0·5	...	...	...	F 120	54
No titanium	85	0·17	7	1	...	4·0 at 100 h	...	...	TS 235	...
No molybdenum	84	0·18	7	...	0·5	...	...	...	F 158	16
Low molybdenum	89	0·10	7	1	0·5	0·129	0·296	0·588	F 3793	23
	101	0·095	7	1	1·0	...	...	...	F 45	61
	87	0·15	7	1	0·5	0·268	5·1	...	TS 1058	...
High molybdenum	116	0·15	7	2·23	0·5	0·106	0·189	0·244	TS 10267	...
Low carbon	97	0·11	7	2	0·5	0·52	...	...	TS 282	...
	100	0·10	7	2	0·5	9·7	...	...	F 263	55
Standard	43	0·15	7	2	0·5	0·081	0·157	0·215	TS 8164	...
	112	0·15	7	2	0·5	0·08	0·161	0·230	F 15190	23
	114	0·15	7	2	0·5	0·10	0·193	0·275	TS 7087	...
	123	0·15	7	2	0·5	0·17	0·346	0·43	TS 6339	...
	115	0·14	7	2	0·5	0·232	0·87	...	TS 1339	...
	113	0·15	7	2	0·5	0·25	2·18	...	F 1752	42
	96	0·14	7	2	0·5	0·25	...	...	F 912	2·2*
	105	0·15	7	2	0·5	2·1	...	...	F 432	46
High carbon	126	0·19	7	2	0·5	0·132	0·242	0·33	TS 8544	...
	107	0·20	7	2	0·5	0·67	...	...	F 814	44
	106	0·176	7	2	0·5	1·6	...	...	F 450	13
Varying chromium	124	0·15	5	2	0·5	0·078	0·18	0·284	TS 7180	...
	125	0·15	8	2	0·5	0·107	0·203	0·256	TS 2044	...
	102	0·13	9	2	0·5	0·07	0·184	0·342	F 7030	...
	109	0·20	9	2	0·5	0·348	1·68	...	F 2038	40
	127	0·16	11	2	0·5	0·031	0·068	...	TS 1518	...

TS test stopped. F fractured. * Broke outside gauge length.

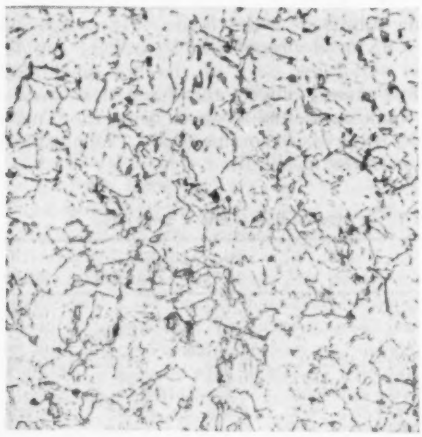
At the conclusion of the vacuum-melting program it was decided to investigate the practical application of 7%Cr steel and several 50-lb hf melts of a selected composition were made in air under flux using ferro-alloys for addition of carbon, silicon, manganese, chromium, molybdenum, and titanium. Later, a 500-lb melt of the composition found to give the best properties at 650°C was made by Wm Jessop and Sons Ltd and rolled to a 2 in. dia. tube by Stewarts and Lloyds Ltd. The heat-treatment normally applied to 7% chromium steels consists of cooling from a temperature of 1 150–1 250°C at such a rate as to retain the carbide-forming element in solution and then tempering at 700–750°C to precipitate the carbide.

Creep testing

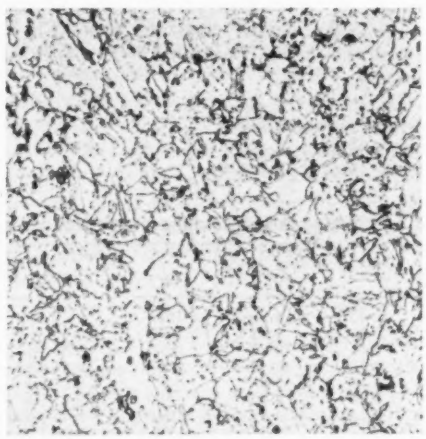
Creep tests were made in a 2-ton capacity creep machine using specimens with a 2 in. gauge length and of 0·357 in. dia. Creep strain was measured by means of mirror extensometers sensitive to 10^{-6} and 10^{-7} mm. The period of soaking at test temperature before the application of load was about 16 h and the furnace was electronically controlled to ±1°C throughout the test. The majority of the creep tests were made at 650°C, a little higher than the intended service temperature.

Binary alloys of iron

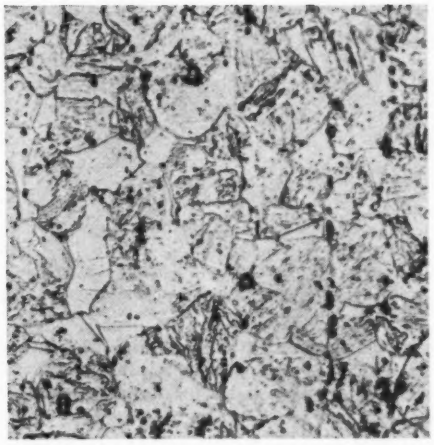
Since there appeared to be no knowledge of the effect of simple additions of alloying elements on the creep resistance of pure iron at temperatures above 538°C[3] a series of preliminary tests was made at 650°C *in vacuo* on simple binary alloys. A sample of pure iron at 650°C broke in 9·5 h under a stress of 0·5 tons/in². Quite small additions of alloying elements sufficed to enable the metal to carry a stress of 2 tons/in² at 650°C for considerable periods, and creep curves for



3 *Steel 113, heat-treated 15 min at 1 150°C, water-quenched and tempered 1 h at 750°C* ×500



4 *Steel 96, heat-treated 15 min at 1 150°C and water-quenched* ×500



5 *Steel 96, heat-treated 15 min at 1250°C and water-quenched* ×500

alloys with additions of 1% of chromium, molybdenum, niobium, titanium, vanadium, and tungsten are reproduced in Fig.1. Chromium exerted a definite though small strengthening effect and the improvements produced by tungsten, vanadium, and molybdenum increased in that order. The most striking effects were produced by titanium and niobium and as little as 0·5% of these elements resulted in alloys which were unbroken after 1000 h.

These results confirmed the value of molybdenum as a ferrite strengthener. When carbon is present, niobium, titanium, and vanadium are ready carbide formers and their value as ferrite strengtheners is very much diminished.

It was already apparent from the work of Crafts and Lamont[4,5] and of Colbeck, Ward, and Rait[6,7] that to obtain an acceptable standard of creep strength with 7% of chromium present it would be necessary to prevent the disappearance of the carbide V_4C_3 or to introduce an equally satisfactory carbide.

A series of steels was therefore produced containing 0·15%C and 7%Cr together with 1 or 2%Mo. To this basic composition were added in turn ½% of the carbide-forming elements vanadium, zirconium, niobium, and titanium. After heat-treatment, tests were made at 650°C and 2 tons/in² and the results are given in Table I.

TABLE III Effect of solution treatment temperature on the structure and creep resistance of steels of the standard composition

Steel	Water-quenched from 1150°C			Water-quenched from 1250°C		
	Grain size	γ/α ratio	Creep strain, %, at 200 h*	Grain size	γ/α ratio	Creep strain, %, at 200 h*
43	Coarse	70:30	0·081	...	...	...
112	Coarse	70:30	0·081	...	...	...
96	Fine	90:10	0·25	Coarse	80:20	0·076
105	Fine	90:10	2·10	Coarse	80:20	0·080
108†	Medium	90:10	0·114	Coarse	80:20	0·060
113	Fine	90:10	0·25	Medium	80:20	not tested

* Tempered at 750°C, tested at 650°C and 5 tons/in²

† Contains 0·2%Si, 0·4%Mn

TABLE IV Effect of casting temperature on the creep strength of steels of standard composition tested at 650°C and 5 tons/in²

Steel	Casting temperature, °C	Creep strain, % At 200 h	At 500 h	At 1000 h
113	1542	0·25	0·68	2·18
121	1547	0·33	0·54	0·87
116	1579	0·106	0·148	0·189
114	1665	0·100	0·148	0·193

All these carbide-forming elements appeared to improve the creep resistance. On the niobium-containing alloy the effect of varying the time of tempering at 750°C was examined, and it appeared that short times of tempering were preferable. The most striking results were produced by the titanium addition, and further work was therefore concentrated on steels containing titanium.

The nature of the carbides present in the steels described in Table I was investigated by X-ray examination of the residues left after dissolving a sample of the steel in a cold solution of iodine in alcohol. When titanium was added, the whole of the carbon appeared as titanium carbide, both before and after the creep test. Zirconium carbide was formed when zirconium was added. The carbide V_4C_3 was not found in the vanadium-containing steels, and a series of isothermal treatments failed to produce it. In the niobium steels, niobium carbide was present after quenching, but after tempering and creep testing the complex carbides $M_{23}C_6$ and M_6C containing chromium and molybdenum were also found.

Variations of composition

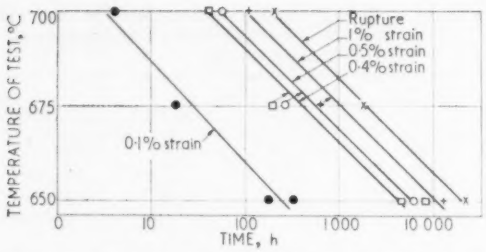
A more thorough examination was made of steels based on the composition 7%Cr, 2%Mo, 0·5%Ti, and, to shorten the program of creep testing, the stress was raised to 5 tons/in². In Table II are shown the effects of variation of basic composition on steels which were tested after heat-treatment for 15 min at 1150°C, water-quenching and tempering for 1 h at 750°C.

Very poor results were found when carbon was very low or when molybdenum or titanium was absent. It was found that 2%Mo gave better creep properties than 1% and one steel with 2¼%Mo (no.116 in Table II) was as strong as those with 2%. Less satisfactory

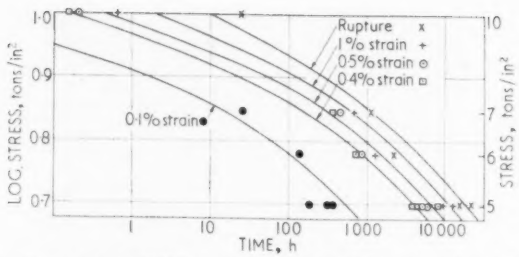
TABLE V Effect of variations in heat-treatment on the creep strength of steel 43 tested at 650°C and 5 tons/in² (tests in order of merit)

Heat-treatment 15 min, 1150°C	Creep strain, % At 200 h	At 1000 h	At 2000 h	Duration of test, h
WQ+1 h 750°C	0·081	0·157	0·215	TS 8164
WQ only	0·090	0·209	...	TS 1925
WQ+1 h 750°C	0·104	0·214	0·280	F 21990
AC only	0·109	0·242	...	TS 1298
OQ only	0·105	0·249	...	TS 1710
AC+1 h 750°C	0·137	0·293	0·41	TS 2827
WQ+1 h 700°C	0·112	0·268	0·464	TS 2353
WQ+1 h 735°C	0·140	0·30	0·575	TS 2465
WQ+½ h 750°C	0·148	0·357	0·515	TS 3098
WQ+2 h 750°C	0·185	0·430	...	TS 1628
WQ+1 h 725°C	0·196	...	...	TS 578
WQ+1 h 775°C	0·34	...	...	TS 407
WQ+16 h 750°C	0·365	...	...	TS 768
OQ+1 h 750°C	0·38	0·593	...	TS 1492
WQ+48 h 750°C	0·62	1·03	...	TS 1080
AC only	0·234	1·76	...	F 1410

WQ water quenched. OQ oil quenched. AC air cooled. F fractured. TS test stopped.



6 *Creep tests at 5 tons/in² on steel 43, heat-treated 15 min at 1150°C, water-quenched and tempered 1 h at 750°C*



7 *Creep tests at 650°C on steels 43 and 112, heat-treated 15 min at 1150°C, water-quenched and tempered 1 h at 750°C*

creep results were obtained when the carbon content was lowered from 0·15% to 0·1% (steels 97 and 100) and raising it to 0·2% (nos.106, 107, 126) gave poor results in two cases but a reasonable one in the third. As far as could be judged from a small number of tests the creep strength was not very sensitive to the chromium content between 5% and 9%Cr. Better properties were again obtained with 11%Cr although this steel should be regarded as in a separate class.

Of all the steels tested no.43 containing 0·15%C, 7%Cr, 2%Mo, and 0·5%Ti was the strongest at 650°C and 5 tons/in². With the exception of the 11%Cr steel no other composition gave as good results and it was decided to study this in greater detail. Mechanical properties at room temperature after water-quenching from 1150°C and tempering for 1 h at 750°C were:

Young's modulus, lb/in²	$29{\cdot}15\times10^6$
Limit of proportionality, tons/in²	22·1
Ultimate stress, tons/in²	49·4
Elongation on $4\sqrt{\text{area}}$, %	25
Reduction of area, %	67

The effect of heat-treatment on steels of the standard composition

When the creep resistance of a steel depends largely on the precipitation of carbide particles it is important to establish the right solution-treatment temperature and the best tempering conditions. The optimum solution-treatment temperature was found to vary somewhat with different steels of the same composition. Microscopic examination of steels as water-quenched from 1150°C showed that there was a difference in grain size and in the proportions of α and γ iron that had been present during solution-treatment. Figure 2 is a photomicrograph of steel which had a coarse microstructure and was good in creep while Fig.3 shows the finer structure of a weaker steel. By raising the solution-treatment temperature, however, most fine-grained steels could be coarsened with an accompanying increase in the proportion of α iron. Figures 4 and 5 are photomicrographs illustrating this coarsening process applied to steel 96 while the relation of that coarsening to creep strength is shown in Table III. It seemed that for most steels 1150°C was the best solution temperature, but some steels needed a still higher temperature to give the best creep properties.

Such small variations in composition as exist are unlikely to be the cause of differences in creep behaviour. Differences in treatment during melting and casting are much more likely to be responsible. A comparison between steels intentionally cast at high and low casting temperatures (*see* Table IV) shows that under the conditions employed a high casting temperature is associated with good creep resistance.

Variations in creep behaviour owing to the rate of cooling from the solution temperature and to changes in tempering procedure are shown in Table V. The best results are given by water-quenching from 1150°C followed by 1 h at 750°C. It seems probable that water-quenching is not essential, for reasonable properties were obtained by oil quenching or air cooling. Relatively low resistance to creep occurs when the tempering temperature is too high or the time of tempering too long.

Expected life to rupture at 621°C and 3 tons/in²

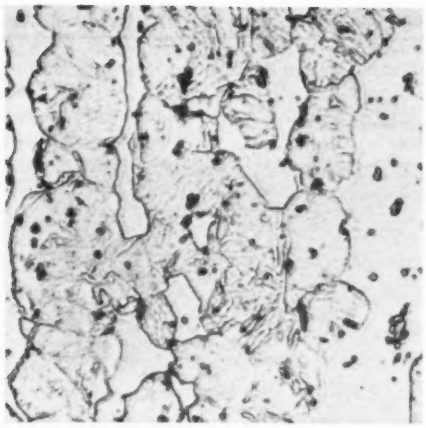
Two steels of the standard composition and heat-treatment were tested at temperatures from 625° to 700°C and stresses from 5 to 10 tons/in². The results are plotted in Figs.6 and 7. It cannot be claimed that there are enough results for accurate estimates to be made, but the fact that one test lasted over 15000 h and another over 21000 h allows some reasonable assumptions to be made. From Fig.6 it is clear that the rupture life of steel 43 would be increased by a factor of 10 for each 25°C fall in temperature, or by a factor of 14·5 for a fall of 29°C from 650° to 621°C. On the other hand, two tests of steel 112 show the rupture life to be increased by a factor of only 3·6 (from 1170 to 4197 h) when the temperature of test falls from 650° to 625°C at 7 tons/in². The corresponding factor for a drop of 29°C would be 4·4.

The slope of the curve of log stress plotted against log life to rupture at a constant temperature of 650°C (Fig.7) indicates that a reduction in stress from 5 to 3 tons/in² would result in a 30-fold increase in life. To arrive at a figure for the life to rupture at 621°C and 3 tons/in² from the life at 650°C and 5 tons/in² one should therefore multiply by a factor lying between $4{\cdot}4\times30$ and $14{\cdot}5\times30$, i.e. between 132 and 435. Thus any steel with a life of 758 h or more at 650°C and 5 tons would be expected to last more than 100000 h at 621°C and 3 tons/in².

CONSTITUTION AND STRUCTURE

A γ-loop occurs in the iron–chromium system and at 7%Cr the transformation from α to γ on heating occurs at about 850°C. When 0·1–0·2%C is added, the carbide $(CrFe)_7C_3$ is in equilibrium with α iron. Addition of 1–2%Mo causes the replacement of $(CrFe)_7C_3$ by $(CrFeMo)_{23}C_6$, and the latter may be wholly or partially replaced by other carbides when carbide forming additions are made.

The steels having useful creep resistance are essentially Fe–Cr–Mo–Ti–C alloys, in which titanium is the

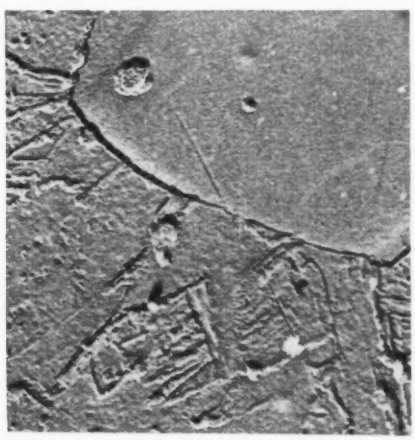


8 *Steel 112, heat-treated 15 min at 1150°C, water-quenched* ×500

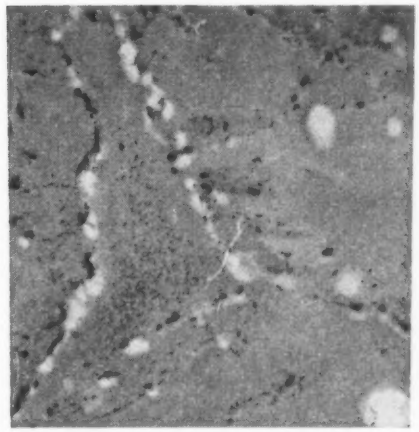
main carbide-forming element. It is convenient to think of them as Fe–C–Ti alloys with 7%Cr and 1% or 2%Mo.

At 1150°C the equilibrium structure of steel 112 is $\alpha+\gamma+$TiC as shown in Fig.8, the TiC being in relatively coarse particles of some 25000 Å dia., easily visible in the optical microscope after quenching. It is probable that more carbon is in solution in the γ than in the α, and that there is more titanium in the α than in the γ. The quantity of α increases when the temperature is raised, as has already been shown. On tempering the quenched alloys at 750°C, further carbides are precipitated in very fine form both from the regions formerly γ, and from the α, but the coarse titanium carbide particles appear to remain unchanged. The precipitation processes differ in the α and γ regions and the creep resistance appears to be controlled by the nature and stability of the precipitates that are formed.

The precipitates are, in general, too fine to be seen in the optical microscope, but they are left undissolved, along with coarser carbide particles, when the alloys are decomposed in an alcoholic iodine solution. The residues may contain particles of all sizes



9 *Steel 105, heat-treated 15 min at 1150°C, water-quenched. Electron micrograph of replica* ×5000



10 *Steel 105, heat-treated 15 min at 1250°C, water-quenched and tempered 1 h at 750°C. Electron micrograph of extraction replica* ×5000

between 25000 Å and 50 Å, and may be subjected to chemical analysis, or examined by X-ray diffraction, electron diffraction, or the electron microscope.

X-ray diffraction powder technique using filtered cobalt radiation λ Kα=1·790 Å, is used to demonstrate the presence and nature of particles down to 1000 Å in size, but the smaller particles give lines that are too diffuse to be detected. Electron diffraction using 60-kV electrons, λ=0·05 Å, shows broadened lines from particles below about 100 Å, fine continuous lines up to about 500 Å, spotty lines up to about 1000 Å, and no pattern from larger particles on account of their thickness. Electron microscopy of the residues reveals the shape of the coarse particles and the fine particles down to about 500 Å, but particles finer than this are not readily dispersed over the support, and gather together into diffuse masses.

Examination of residues cannot show whether the particles came from the α or the γ regions. For this, electron microscopy of the solid sample is necessary, and reveals particles down to about 300 Å. The shadowed metallic replica (Fig.9) and the extraction replica (Fig.10) have been employed. In the latter method[14] the specimen is etched through a Formvar film, and particles below 5000 Å are retained in the film in their proper relative positions. These particles may be examined by electron diffraction, and identified with certainty. Larger particles are not retained, but are detected by means of the impressions made on the contact surface of the replica.

The results of examination of residues extracted from some of the titanium-containing steels are given in Table VI, where specimens are placed in order of merit as determined by their behaviour in creep. X-ray examination shows that TiC is always present and that steels containing $M_{23}C_6$ tend to be not so good in creep. After long time tests at 650°C, the residues increased in quantity and contained Fe_2Ti and M_6C in addition to TiC. Chemical analysis showed a corresponding increase in iron and molybdenum, as shown in Table VII.

Electron diffraction examination of the residues of the steels with better creep properties showed lines of titanium carbide either broad and continuous, indi-

TABLE VI Examination of carbide residues of steels containing titanium

Steel	Departure from composition	Tempering time at 750°C after water-quenching from 1150°C	Creep strain, %, tested at 650°C, 5 tons/in² At 200 h	At 1000 h	Carbides identified by X-rays	Particle size by electron microscope Large	Small	Electron diffraction patterns
43	...	1 h	0·081	0·157	TiC	Several μ	Barely resolved	TiC with line broadening corresponding to a size of about 50 Å
43	...	1 h	0·081	0·157	TiC+Fe_2Ti+trace of M_6C	†~1 μ	†500 to 2000 Å	† Spotty TiC pattern with faint additional lines on some plates
112	...	1 h	0·080	0·161	TiC+1 ul	ND	up to several 1000 Å	TiC
96	...	1 h*	0·076	0·185	TiC+$M_{23}C_6$+1 ul	ND	up to several 1000 Å	Spotty TiC pattern
43	...	None	0·090	0·209	TiC	1–5 μ	ND	Single crystal spot patterns. Some faint unidentified lines on one plate
43	...	None	0·090	0·209	TiC+Fe_2Ti+M_6C	‡ND	‡ Up to 500 Å	‡ Spotty TiC pattern with heavy background. Possible additional unidentified lines
108	0·2%Si, 0·4%Mn	1 h	0·114	0·328	TiC+1 ul	ND	Several 1000 Å	TiC
96	...	1 h	0·25	...	TiC+$M_{23}C_6$+1 ul	ND	~300 Å	One unidentified pattern. Other different patterns show possible TiC
87	1%Mo	1 h	0·268	5·1	TiC+$M_{23}C_6$	~5 μ	~2500 Å	No satisfactory pattern
43	...	16 h	0·365	...	TiC	~1 μ	Up to 1000 Å	TiC pattern with spots on lines, indicating larger particle size. Additional continuous lines, possibly $M_{23}C_6$
87	1%Mo	None	0·395	...	TiC+faint ul	~5 μ	~2500 Å	No satisfactory pattern
97	0·1%C	1 h	0·52	...	TiC+1 ul	~1 μ	<1000 Å	Spots on continuous lines of TiC pattern. Considerable background.
90	0·2%Si, 0·4%Mn 1%Mo	1 h	1·0	...	TiC+3 ul+$M_{23}C_6$	ND	>1000 Å	Single crystal spot pattern only

* Solution treatment temperature 1250°C. ul unidentified line. ND not determined. † after 8164 h creep test. ‡ after 1925 h creep test.

cating very fine particle size, or with fine spots on a continuous background indicating the presence of 500 – 1000 Å particles. Some steels with poor creep properties showed extremely broad titanium carbide lines, others a good pattern of unidentified constituent, and others no satisfactory pattern at all. The best creep properties were clearly associated with a simple pattern of titanium carbide particles of 1000 Å or less.

The untempered and very lightly tempered samples had good creep resistance although no fine titanium carbide was detected. They were, however, heated for several hours in the testing machine at 650°C before the load was applied, and examination of a water-quenched sample tempered for 24 h at 650°C showed that fine titanium carbide had been precipitated during this period. The precipitated titanium carbide increased in grain size as the time of tempering was increased. After 16 h tempering at 750°C, some of the titanium carbide particles were over 1000 Å, and lines identifiable with $M_{23}C_6$ had also appeared. By this time the creep resistance had deteriorated appreciably. Table VIII summarizes the relationship found in this series between the particle size of the titanium carbide as estimated from the electron diffraction pattern and the creep resistance of the steel.

The residue from a test piece that had been stressed for 8164 h at 650°C after having been tempered 1 h at 750°C contained titanium carbide particles of 500–2000 Å. The particles had therefore grown appreciably during the test, but the creep rate at the end of the test was still low, and of the order of 0·03% per 1000 h. A second sample of this steel, tested under the same conditions, had a life of 21990 h. If it is assumed that the rate of growth is governed principally by the rate of diffusion of alloying elements in α iron, the rate of growth at 621°C will be about one-fifth of that at 650°C. There is thus reason to believe that the extrapolations in Fig.10 can be relied upon to 100000 h at least.

Figure 11 shows the electron diffraction patterns of residues from steel 43 after 1 h and 16 h tempering at 750°C, and after 8164 h creep testing at 650°C.

When solid specimens of the alloys were examined in the as-quenched condition with the electron microscope, the regions which had been γ at the moment of quenching were distinguished from the α regions by an acicular substructure (Fig.9). Occasional large carbide particles representing the titanium carbide undissolved at the quenching temperature were seen. Figure 12 illustrates the structure after tempering of a steel which was poor in creep. The comparatively large particles, 5000–15000 Å, are in all probability the $M_{23}C_6$ particles detected in the extraction residues by X-ray diffraction. Steels which are good in creep have an entirely different structure after being tempered for 1 h at 750°C. The α regions are filled with a dense

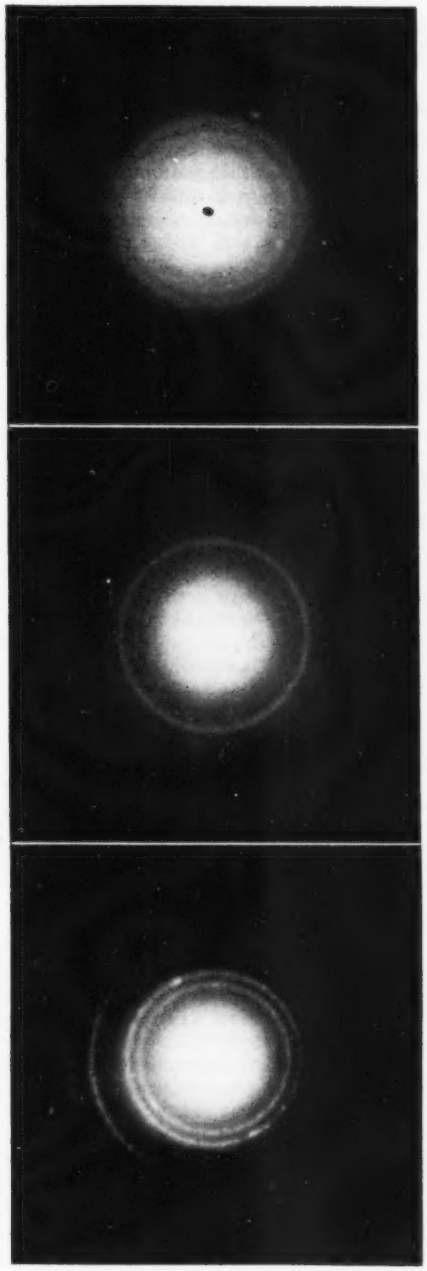
TABLE VII Chemical analysis of carbide residue from steel 43

Heat-treatment	Element, % Fe	C	Cr	Mo	Ti
15 min 1150°C, WQ+1 h 750°C	13·1	16·0	6·0	19·5	42·7
15 min 1150°C, WQ+1 h 750°C+ 8164 h test at 650°C	28·2	6·8	6·1	32·2	23·0

TABLE VIII Relation of tempering time to creep and carbide size

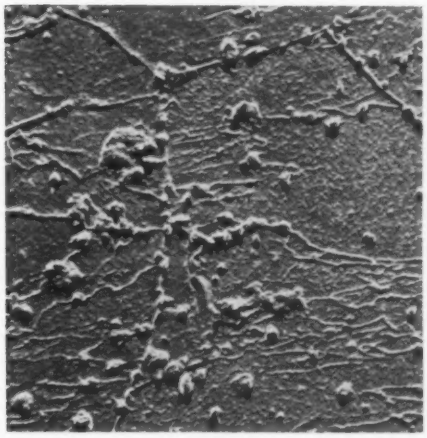
Tempering treatment after 15 min at 1150°C and WQ	Creep test at 650°C, 5 tons/in² Creep strain,% At 200 h	At 500 h	At 1000 h	Particle size from electron diffraction, Å
1 h at 750°C	0·081	0·121	0·157	~50
2 h at 750°C	0·186	0·298	0·430	<1000
16 h at 750°C	0·365	0·47	...	1000
48 h at 750°C	0·620	0·80	1·03	2500
1 h at 735°C	0·148	0·23	0·30	200

cloud of very fine particles probably of not more than 1000 Å while the γ regions show long threads of precipitate outlining the boundaries of the acicular substructure (Fig.13). Coarse particles are found at the boundaries of the α and γ regions and occasionally the



(a) 15 min at 1150°C, water-quenched and tempered 1 h at 750°C
(b) 15 min at 1150°C, water-quenched and tempered 16 h at 750°C
(c) 15 min at 1150°C, water-quenched, tempered 1 h at 750°C, and tested for 8164 h at 650°C

11 *Electron diffraction patterns of extracted residues of steel 43*

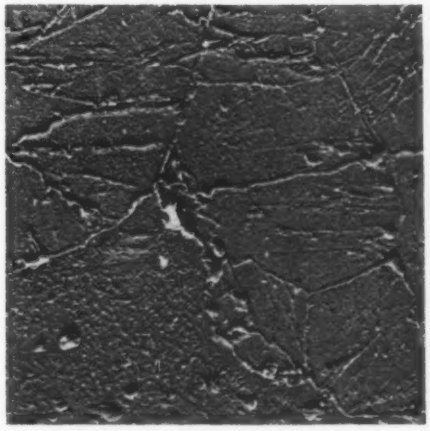


12 *Steel 105, heat-treated 15 min at 1150°C, water-quenched and held 1 h at 750°C. Electron micrograph of replica* ×5000

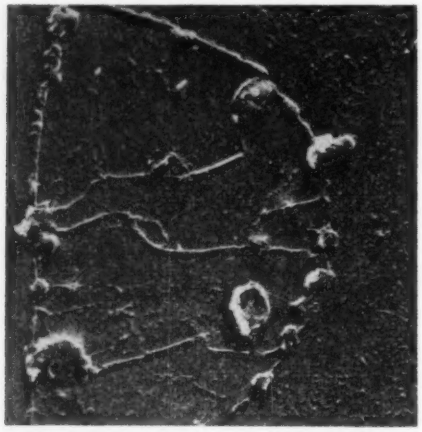
needles of the γ structure contain very fine precipitate. An extraction replica (*see* Fig.10) displayed the same two types of area as are shown by the shadowed metallic replica, and the small precipitated particles carried into the replica film were proved by electron diffraction to be titanium carbide in both types of area. Figure 14 is an electron micrograph of the alloy tested for 8164 h at 650°C. The large angular particles may well be the Fe_2Ti detected in the extraction residues by electron diffraction. The dispersed phase in the α region has coarsened appreciably but many particles below 1000 Å still exist.

Welds in extruded tube

A 50-lb vacuum-melted ingot (steel 115) of the standard composition was staved and extruded to $1\frac{7}{8}$ in. outside dia. tube by the Chesterfield Tube Co. A piece from the top of the ingot was forged and rolled to $\frac{5}{8}$ in. bar. The tube was subsequently cut transversely and joined again by welding so that longitudinal test pieces could be made to include a portion of the weld. The results of creep tests at 650°C and 5 tons/in² are



13 *Steel 96, heat-treated 15 min at 1250°C, water-quenched and held 1 h at 750°C. Electron micrograph of replica* ×5000



14 *Steel 4%, heat-treated 15 min at 1150°C, water-quenched and held 1 h at 750°C and 8164 h at 650°C. Electron micrograph of replica* ×5000

given in Table IX. As rolled and heat-treated steel 115 was not so good as some others of the standard composition (*see also* Table II). The extruded tube, even when given a high solution treatment temperature of 1250°C before tempering, was not so good as the rolled and heat-treated bar. Welding the heat-treated tube reduced its life to about one quarter. The benefits of heat-treatment do not seem to have been wholly removed by welding for the life of non-heat-treated tube as welded was only half that of the heat-treated and welded tube.

Steels melted in air

Several 50-lb hf melts of the standard composition were made in air, using ferroalloys for the main additions of silicon, manganese, chromium, molybdenum, and titanium. Swedish iron, ferrochromium, and chromium were first melted under a flux consisting of equal parts by weight of lime and alumina. Additions were made in the following sequence: ferromanganese, ferromolybdenum, carbon, and ferrotitanium. In the early melts losses of titanium up to 90% were experienced but these were reduced to 30–40% by (*a*) avoiding excessively high temperatures during melting (1580–1600°C was found to be the best range for casting temperature), (*b*) making ferrotitanium the last addition before pouring, and (*c*) holding the ferrotitanium under the melt in an inverted mild-steel cup. Seven steels had compositions which were near to that required and their analyses are given in Table X.

The heat-treatment which gave the best creep properties in vacuum-melted material, namely 15 min at 1150°C water-quenching and tempering for 1 h at 750°C, was also applied to the air-melted steels. As shown in Table X steels in which the titanium was too high or too low or carbon too high were not good in creep. Steels 145 and 146 gave good results and steel 146 was further improved by solution-treatment at 1250°C before tempering.

The nitrogen content of air-melted steels was of the order of 0·01% as compared with about 0·003% for vacuum-melted steels, but there was not sufficient evidence to say that this difference had any relation to difference in creep behaviour.

TABLE IX Creep tests at 650°C and 5 tons/in² on steel 115

Form	Heat-treatment	Creep strain, % At 200 h	At 1000 h	Duration of test, h
⅝-in. hot rolled bar	15 min 1150°C, WQ + 1 h 750°C	0·232	0·87	TS 1339
Tube	15 min 1250°C, WQ + 1 h 750°C	0·27	1·67	F 1788
Tube with weld	None	...	...	F 238
Tube with weld	15 min 1250°C, WQ + 1 h 750°C before welding	0·86	...	F 450

WQ water-quenched. TS test stopped. F fractured.

Experimental superheater tube

A 500-lb melt of steel of the standard composition was made in air in a high-frequency furnace by Wm Jessop and Sons Ltd whose chemical analysis of the cast was as follows:

	%		%
C	0·13	Cr	6·8
Si	0·26	Mo	2·26
Mn	0·54	Ti	0·60
Ni	0·17		

Stewarts and Lloyds Ltd were supplied with two 4-in. dia. machined billets from the above cast. The two billets were then bored, followed by heating to 1160–1200°C to enable the tube to be formed in Pilger rolls. Subsequently the tube was cold drawn to 2-in. outside dia. and ¼-in. wall thickness. After heat-treatment and bend tests a length of tube was welded into a superheater by CEGB. A sample of the tube, which was stated to have been held at 1150°C for 15 min, air-cooled, and tempered for 1 h at 750°C, was tested at 650°C and 5 tons/in² and had a life of 187 h. Another piece of tube as cold drawn and annealed was water-quenched from 1250°C and tempered for 1 h at 750°C. Under the same conditions of test this tube broke in 476 h.

The results of tests on this tube, heat-treated and tested at 650°C and 5 tons/in² by Wm Jessop and Sons Ltd are as follows:

Water-quenched from 1150°C and tempered:	840 h to rupture
Air-cooled from 1150°C and tempered:	529 h to rupture

DISCUSSION

There is every prospect that a ferritic steel can be made which is resistant both to creep and oxidation in the temperature range 600–650°C. Studies of vacuum-melted steel have shown that under a stress of 5 tons/in² at 650°C rupture lives of 10000–20000 h may be obtained, with a corresponding expectation of a useful life of well over 500000 h at 621°C and 3 tons/in².

When steels are made in the laboratory under more nearly practical conditions, namely air-melting, preliminary tests indicate that it is more difficult to maintain the above standards of creep resistance. It is unlikely that additions of manganese and silicon *per se* prevent the standard of creep resistance being reached, but modification in heat-treatment or melting procedure may be necessary.

The difference between the creep-behaviour of air-melted and vacuum-melted steel is less than the difference found in vacuum-melted steels owing to variations in composition and heat-treatment. It is therefore likely that the optimum conditions of com-

TABLE X Creep tests at 650°C and 5 tons/in² on air-melted steels

Steel	Chemical analysis, % C	Si	Mn	Cr	Mo	Ti	Creep strain, % At 200 h	At 500 h	At 1000 h	Duration of test, h
131	0·18	0·16	0·46	7·56	2·20	0·39	0·505	1·04	...	TS 670
141	0·20	0·24	0·43	6·69	2·10	0·51	0·710	...	...	TS 290
142	0·16	0·13	0·28	6·51	2·13	0·44	0·570	...	...	TS 337
145	0·15	0·20	0·43	6·69	2·06	0·50	0·182	0·30	0·454	F 5300
146	0·16	0·19	0·55	6·77	2·16	0·56	0·147	0·236	0·347	F 7578
146*	0·16	0·19	0·55	6·77	2·16	0·56	0·103	0·153	0·215	TS 6526
147	0·16	0·12	0·42	6·82	1·97	0·65	0·475	...	...	TS 451
148	0·14	0·16	0·50	6·62	2·07	0·84	10·06	...	...	F 283

* Solution treatment temperature 1250°C. TS test stopped. F fracture.

position and heat-treatment of air melted steels has not yet been found. Steels containing silicon and manganese have a higher γ/α ratio than normal and this might be corrected by lowering the carbon content, increasing titanium and molybdenum, or by raising the solution-treatment temperature.

Tests on a tube made from a 500-lb commerical melt indicate that it may be necessary to lower the standard required to a life of 500–800 h at 650°C and 5 tons/in², probably corresponding to a life of over 100000 h at 621°C and 3 tons/in².

It is common experience that many trials are necessary before the standard reached in laboratory results is reproduced in tests on a practical scale. In the present work only one larger melt has been made, compared with 149 laboratory melts and further work on a larger scale is obviously needed. The reduction in life to rupture from 20000 h for rolled bar of vacuum-melted steel to 500–800 h for a superheater tube made from a larger scale air melt appears to be mainly due to the tube drawing process. It would be most useful to investigate the nature of this deterioration and the means of overcoming it. Even if the expected improvement could not be obtained, a life of 500–800 h at 650°C and 5 tons/in² represents an improvement on existing $2\frac{1}{4}$%Cr–1%Mo steel in respect of creep resistance, quite apart from the greatly increased resistance to scaling.

Variation in creep behaviour owing to composition and heat-treatment (Tables II and V) call for further discussion and the following comments are based on observations with optical and electron microscopes and on the examination of carbide residues. High resistance to creep in a 7%Cr steel seems to depend on the solution of titanium and carbon at a temperature of about 1150°C and the precipitation of particles of TiC not larger than 1000 Å on tempering. This depends upon the constitution at the solution treatment temperature and this again depends on composition, grain size, and solution-treatment temperature.

Variation in chromium content from 5% to 9% has little effect on creep behaviour and there is therefore no reason to believe that the changes of constitution of the steel introduced by chromium are of vital importance. Contents of carbon, molybdenum, and titanium on the other hand are critical and must be such that the structure at the solution-treatment temperature is $\alpha+\gamma+$TiC with a γ/α ratio of about 70:30. If carbon is too low or molybdenum and titanium too high the equilibrium structure both at the solution temperature and the tempering temperature is $\alpha+$TiC. In the absence of γ there is insufficient carbon in solution to come out as fine TiC particles on tempering. If the carbon is too high or the molybdenum and titanium too low there is no α at the solution temperature and consequently very little titanium in solution and very little TiC precipitated. Under these conditions $M_{23}C_6$ tends to precipitate in preference to the more desirable carbide TiC. The formation of $M_{23}C_6$ is also promoted by too high a tempering temperature. Raising the solution temperature tends to reduce the γ/α ratio, which may often be a good thing, and to increase the grain size which again is beneficial.

CONCLUSIONS

1. Ferritic steels with 5–11%Cr have been made from high-purity materials melted and cast *in vacuo*, and these have proved to be very much better than existing Cr–Mo and Cr–Mo–V steels of lower chromium content in their resistance to creep at 650°C.

2. The best composition found in this range of chromium content was 0·15%C, 7%Cr, 2%Mo, 0·5%Ti, and the lowest creep rate at 650°C and 5 tons/in² was obtained after 15 min at 1150°C, water-quenching and tempering for 1 h at 750°C.

3. The type of structure giving good resistance to creep is large grained $\alpha+\gamma+$TiC at the solution treatment temperature with a γ/α ratio of about 70:30 and with fine particles (1000 Å or smaller) of TiC coming out of solution on tempering.

4. A casting temperature not less than 1570°C seems desirable as lower temperatures give fine-grained structures and poor creep properties. It is possible to restore such a steel by water-quenching from 1250°C instead of 1150°C, and tempering.

5. Air-melted steels of commercial composition are somewhat weaker at 650°C than vacuum-melted steels made from pure materials.

6. Small variations in composition lead to changes in structure and therefore to variations in creep properties. It was found to be more difficult to control the composition of an air melt than that of a vacuum melt.

7. From a practical point of view a steel likely to be used for superheater tubes should be weldable and should retain a measure of creep strength after welding. A tube has been made from a vacuum-melted steel and successfully welded. As heat-treated and welded the life to rupture at 650°C and 5 tons/in² is about one-quarter of that of the heat-treated tube.

ACKNOWLEDGMENTS

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APPENDIX Chemical analyses of steels, %

Steel	C	Si	S	P	Mn	Ni	Cr	Mo	Cu	Al (Sol)	Al (Insol)	O	H	N	Ti	Other element
30	0·15	ND	ND	ND	ND	ND	6·98	1·00	ND	ND	ND	0·0006	0·00003	0·002	...	0·495Zr
35	0·15	ND	ND	ND	ND	ND	6·86	1·00	ND	ND	ND	0·0006	0·00006	0·0013	0·52	...
39	0·15	ND	0·0067	ND	0·021	ND	6·89	0·90	ND	ND	ND	ND	ND	ND	...	0·51Nb
40	0·146	ND	ND	ND	ND	ND	6·97	1·89	ND	ND	ND	ND	ND	ND	...	1·06Nb
42	0·15	ND	ND	ND	ND	ND	7·02	1·87	ND	ND	ND	ND	ND	ND	...	0·49V
43	0·152	0·05	0·0067	0·0042	0·010	0·02	6·94	2·11	0·02	0·003	0·003	0·001	0·00005	0·003	0·53	...
44	0·006	ND	ND	ND	ND	ND	6·42	0·93	ND	ND	ND	ND	ND	ND	0·52	...
84	0·18	0·042	ND	ND	ND	ND	6·93	ND	ND	ND	ND	ND	ND	ND	0·46	...
85	0·17	ND	ND	ND	ND	ND	6·89	ND	ND	ND	ND	ND	ND	ND	...	...
87	0·15	ND	ND	ND	ND	ND	6·98	0·97	ND	ND	ND	0·001	0·00008	0·004	0·57	...
89	0·10	ND	ND	ND	ND	ND	6·87	0·99	ND	ND	ND	0·0007	0·00008	0·004	0·48	...
90	0·15	0·16	ND	ND	0·04	ND	7·03	0·98	ND	ND	ND	0·001	0·00007	0·0015	0·50	...
94	0·05	ND	ND	ND	ND	ND	6·84	0·99	ND	ND	ND	ND	ND	ND	0·43	...
96	0·14	0·012	0·004	0·019	<0·005	0·018	7·06	2·00	0·019	0·002	0·002	0·001	nil	0·005	0·47	...
97	0·11	ND	ND	ND	ND	ND	6·84	2·05	ND	ND	ND	0·001	nil	0·002	0·45	...
100	0·095	ND	ND	ND	ND	ND	7·00	2·05	ND	ND	ND	0·001	0·00004	0·0015	0·50	...
101	0·095	ND	ND	ND	ND	ND	6·97	0·99	ND	ND	ND	0·001	0·00007	0·00075	1·02	...
102	0·13	ND	ND	ND	ND	ND	9·02	1·95	ND	ND	ND	0·001	0·00009	0·001	0·49	...
105	0·15	0·013	0·004	0·019	<0·005	0·015	7·00	1·99	0·013	0·002	<0·001	ND	ND	ND	0·53	...
106	0·176	ND	ND	ND	ND	ND	7·00	1·98	ND	ND	ND	ND	ND	ND	0·47	...
107	0·20	ND	ND	ND	ND	ND	7·00	1·90	ND	ND	ND	ND	ND	ND	0·50	...
108	0·15	0·19	0·01	0·001	0·45	0·018	6·30	1·96	0·014	0·004	<0·001	ND	ND	ND	0·50	
109	0·20	ND	ND	ND	ND	ND	9·01	1·95	ND	ND	ND	ND	ND	ND	0·50	...
112	0·15	0·008	0·0045	0·021	<0·005	0·014	7·01	2·00	0·011	0·004	0·002	ND	ND	ND	0·49	...
113	0·15	0·009	0·006	0·018	<0·005	0·011	6·96	1·98	0·009	<0·001	<0·001	ND	ND	ND	0·50	...
114	0·15	0·006	0·005	0·018	<0·005	0·011	6·92	2·00	0·010	0·005	0·001	ND	ND	ND	0·50	...
115	0·14	0·010	0·004	0·010	<0·005	0·009	6·93	2·00	ND	0·004	0·001	ND	ND	ND	0·50	...
116	0·15	0·007	0·004	0·001	0·053	0·017	6·96	2·23	ND	0·001	0·002	ND	ND	ND	0·50	...
121	0·15	0·007	0·006	<0·001	0·055	0·045	6·99	2·07	ND	ND	ND	ND	ND	ND	0·50	...
123	0·15	0·195	0·006	0·003	0·45	0·042	6·99	2·00	ND	ND	ND	ND	ND	ND	0·50	...
124	0·15	0·013	ND	ND	0·06	0·025	5·13	2·00	ND	ND	ND	ND	ND	ND	0·50	...
125	0·15	0·005	ND	ND	0·06	0·019	8·07	2·00	ND	ND	ND	ND	ND	ND	0·50	...
126	0·19	0·007	0·0065	0·002	0·06	0·016	7·08	1·98	ND	ND	ND	ND	ND	ND	0·51	...
127	0·16	0·006	0·007	0·002	0·055	0·019	11·10	2·00	ND	ND	ND	ND	ND	ND	0·51	...

ND not determined

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Some observations on hydrogen cracks

Konrad Kornfeld

SYMPTOMS OF HYDROGEN EMBRITTLEMENT

IT IS WELL KNOWN that electroplating is a cause of cracking under the influence of hydrogen which has been dissolved in the metal during processing. There are many factors on which the serviceability of the plated articles depends: variables of the material, generalized as hydrogen sensitivity; fluctuations in preparation for plating and in electrolytic operations; and the time period between the dissolution of hydrogen and its precipitation, which may be carried out as a heat-treatment.

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The author lives in Ottawa, Canada.

SYNOPSIS

The appearance of fractures and cracks occurring in plated machinery parts is described. Cracks of a shape known from service failures may be produced in a guided notched bend test on plated sheets. 1760

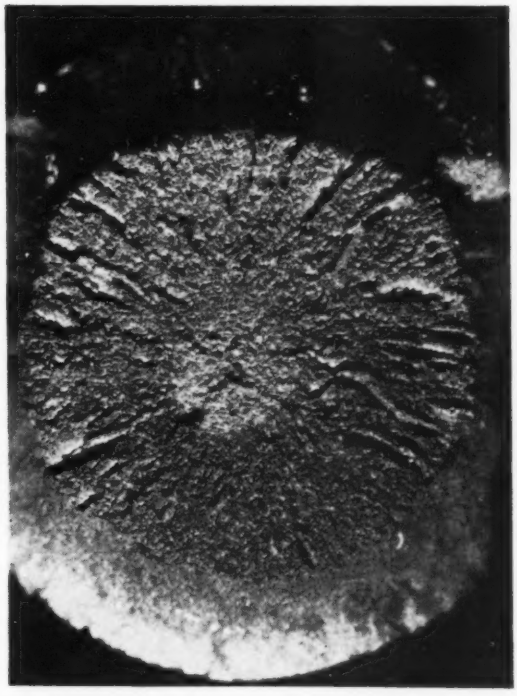
It appears that there is no acceptable method of testing, for assessing the freedom from any tendency to form cracks at unexpected low stress levels. The notched impact test cannot detect the tendency to crack under the influence of hydrogen because such cracks form and propagate at lower speeds than those

TABLE I Mechanical properties of samples from plated forgings

Sample description	0·02% proof stress, tons/in²	0·1% yield strength, tons/in²	0·2% yield strength, tons/in²	UTS, tons/in²	Elong. ($R=4{\cdot}5\sqrt{A}$) %	Reduction in area, %
Forging no.2 as-received average of four tests	77·700	80·468	81·089	86·258	12·88	45·39
% variation in above	0·82	0·94	1·10	1·04	6·21	6·48
Forging no.2, 200°C 25 h, average of four tests	77·807	80·435	81·151	86·241	13·30	50·66
% variation in above	0·74	0·89	1·09	0·48	6·77	7·11
% change by heat-treatment	*	*	*	*	+3·26	+11·61
Forging no.3 as-received average of four tests	79·796	82·229	83·201	88·280	11·80	46·52
% variation in above	0·78	1·02	1·30	0·77	23·73	31·02
Forging no.3, 200°C 25 h, average of four tests	78·819	81·826	82·718	88·344	12·80	48·48
% variation in above	1·78	1·58	1·52	1·02	4·69	13·05
% change by heat-treatment	−1·22	−0·49	−0·58	+0·07	+8·47	+4·21
Forging no.5 as-received average of four tests	81·678	84·518	85·506	91·520	10·90	43·37
% variation in above	3·35	0·88	1·31	0·88	11·01	2·81
Forging no.5, 200°C 25 h, average of four tests	82·424	85·044	85·967	91·912	11·20	42·85
% variation in above	0·73	1·40	1·31	0·74	16·96	16·22
% change by heat-treatment	+0·91	+0·62	+0·53	+0·04	+2·75	−1·20

* Less than 20% of the variation within the sample.

applied in impact testing.[1] The loss of ductility, as represented by the reduction of area in the tensile test,[2] although responsible for the term 'hydrogen embrittlement', may be determined only by comparison between untreated and treated test pieces of some relatively thick stock: the results scatter considerably. Special tests developed for individual cases[3] or for research purposes require special materials of high hydrogen sensitivity[4] or relate to particular stressing conditions.[5] Therefore they are inadequate for general inspection purposes. The hydrogen cracking resulting in decrease of load-carrying cross-section in 'delayed' fracturing[6] or 'static fatigue'[7, 8] becomes a menace, and necessitates efforts aimed at finding methods of inspection which can eliminate the invisibly damaged metal.



1 *Nodular fracture, with a brighter centre, of a tensile test piece extracted from a forging with hydrogen cracks. Steel heated 25 h at 200°C before testing (Forging 5 from Table I in the 'heat-treated' condition)* ×20

Examples of some symptoms accompanying hydrogen cracks forming are quoted in the following paragraphs in an endeavour to initiate discussion on failure diagnoses and on the possible methods of inspection of plating processes.

OBSERVATIONS ON FRACTURES

The well known effects of hydrogen content on the appearance of fractures containing 'flakes'[9] and 'fish-eyes'[1] encourage investigation. The tensile test pieces with round cross-sections frequently give a 'nodular fracture',[2] which was thought to be connected with hydrogen embrittlement. Nevertheless such fractures have been observed on steels with reduction of area exceeding 65%. The nature of nodular fractures was observed on test pieces of $\frac{1}{4}$ in. dia. and 1 in. gauge length extracted parallel to the grain of several forgings. These cracked in service under the influence of hydrogen introduced by two plating operations. The test pieces from alternating neighbouring positions were tested in two groups, one was in the as-received condition, the other was heated for 25 h at 200±1°C. The results are listed in Table I.

Out of the 24 test pieces, 23 had nodular fractures irrespective of treatment. In some of the test pieces the radial ridges reached the centre, while others had brighter flat central areas, but bore no resemblance to a flake. The light centres were found in all heat treated test pieces (Fig.1).

Examination of celluloid replicas of the fractures at higher magnifications[10] indicated no difference between the central bright spot and the nodular portion of the fractures, which was due to shear effects between fibres. As seen in Table I neither the reduction of area nor the appearance of test piece fractures can be accepted as proof of hydrogen embrittlement.

Characteristic fractures were revealed by cuts directed perpendicular to the ends of cracks in cadmium- and chromium-plated parts. Figure 2 represents a surface of an 'opened' crack running through nearly one-third of the circumference of a tubular part. A similar crack is shown in Fig.3 to enable discrimination between this kind of fracture and those caused by fluctuating load fatigue. In hydrogen cracking the layers tend to be straight, equispaced, and without a nucleus.

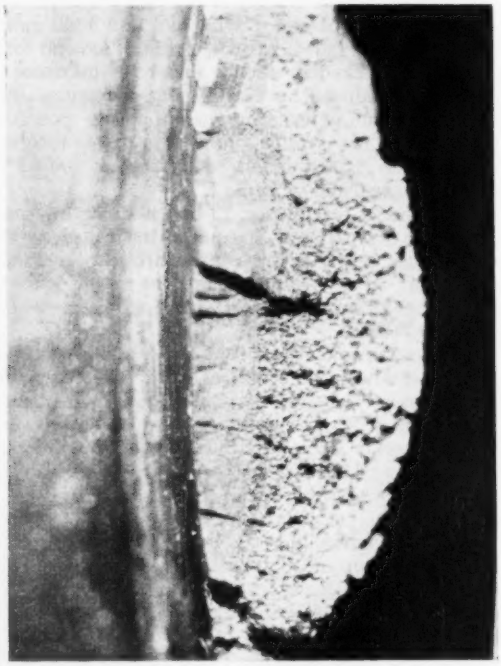
2 *Characteristic surface of hydrogen crack formed during service. Crack initiated in the central area with coarse-grained appearance* ×5

METALLOGRAPHY OF HYDROGEN CRACKS

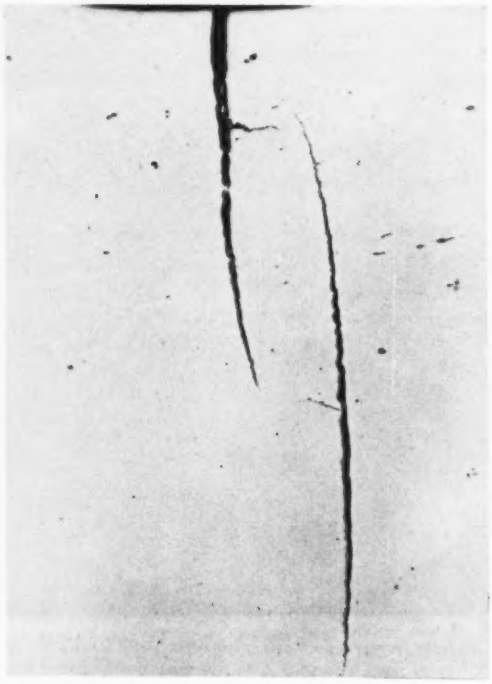
The main direction of hydrogen cracks is usually well defined, although frequent smaller cracks intersecting, or rather entering, into the basic ones are not uncommon. Figure 4 illustrates a case with several types of cracks; the 'main' cracks are both opened to the surface and hidden inside, also there are 'tributary' cracks running nearly perpendicular to the main ones, which are eventually interconnected. The tributaries may sometimes be very thin (Fig.5) and they normally start from non-metallic inclusions or a run between inclusions. The thickness of the tributaries is frequently of the same order as that of the grain boundaries. A weak point on the surface such as an embedded scale (Fig.6) or a grit blasting fold[11] may direct the cracks towards the surface.

The word 'tributary' was purposely used for defining the small hydrogen cracks because their shape strikingly resembled a river. The sources of cracks are found around inclusions and sometimes at spheroidized cementite particles. At times the cracks widen by running through several inclusions, or by meeting until a larger common outlet (not excluding a delta) is found. This course of cracks appears to be in good agreement with the theory of molecular hydrogen pressure[12] in the observed cases of moderately stressed parts working at ambient temperatures. Without the hydrogen gas pressure contribution[13] it would be difficult to explain the course of the cracks. Metallographic observations do not throw any light on the highly reversible dissolution mechanism.

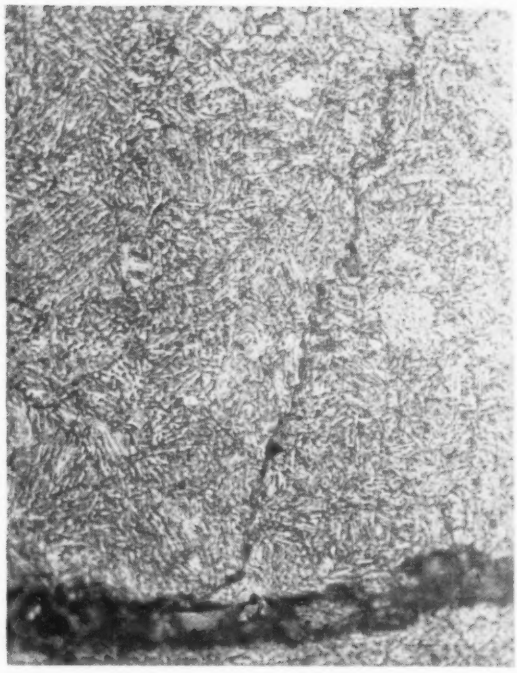
The examination of celluloid replicas of fractures[10] confirmed the scheme described, i.e. pooling of the



3 *Surface of a hydrogen crack formed during service on about 10% of the cross-sectional area of a chrome-plated pivot in 75–95 tons/in² steel* ×10

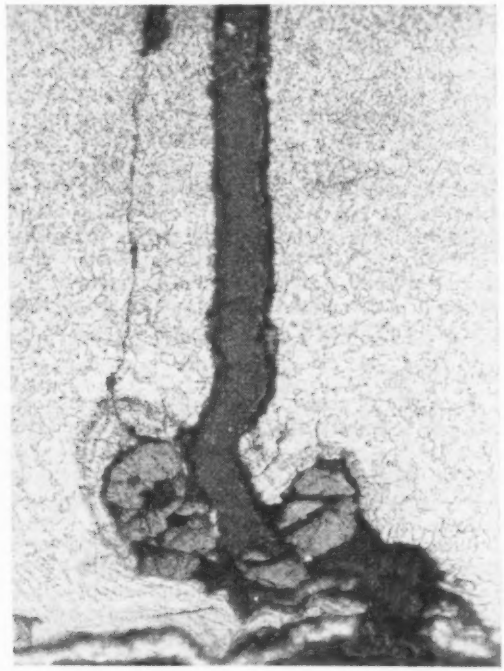


4 *Section through a family of hydrogen cracks, unetched* ×50

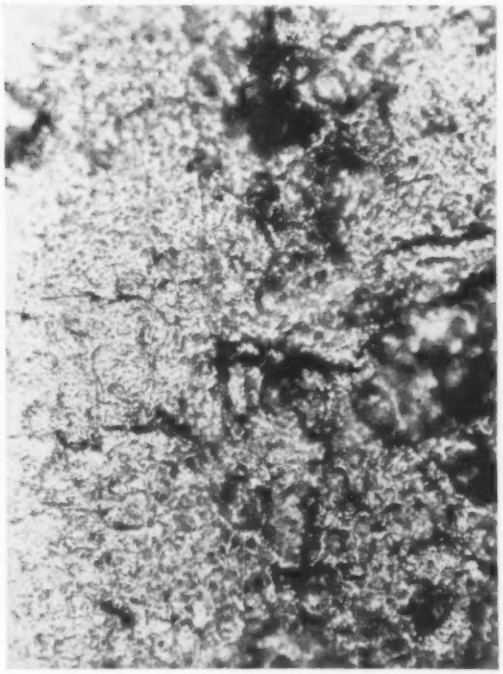


5 *'Tributary' crack running through inclusions towards the main crack in a 80 tons/in² steel, 2% Nital etch* ×750

gas. Tributaries may be found in large numbers on the fractures, particularly on the boundaries between the coarse grained and fine-grained layers on fractures of



6 *Outlet of a crack towards a scale residue on the surface, 2% Nital etch* ×250

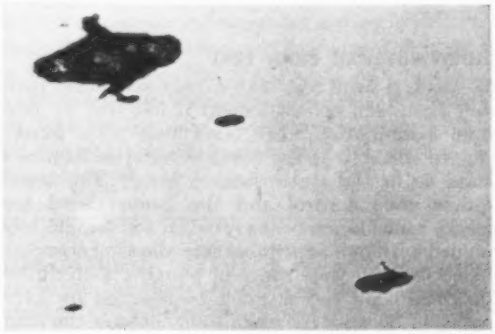


7 *Boundary zone between smooth and 'grainy' zone in a fracture similar to Figs.4–5, showing distribution of 'tributary' cracks, celluloid replica* ×100

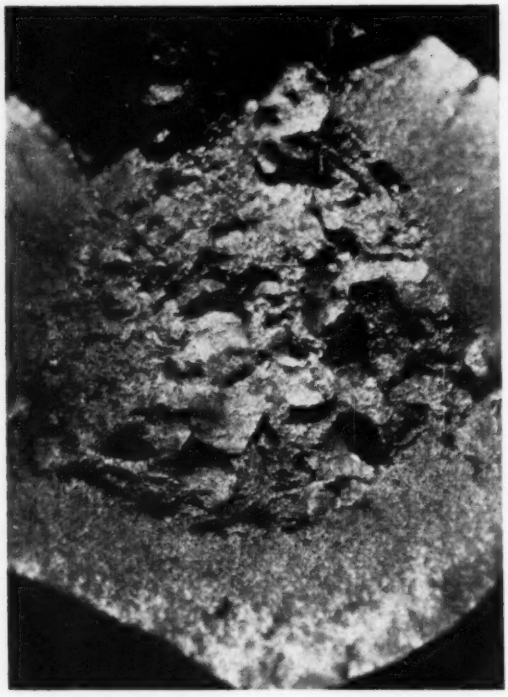
the types shown in Figs.2 and 3. The replica (Fig.7) indicates that the granular appearance of the characteristic layer results from many tributaries in this area and from their intersections.

During the investigation of forgings, for which the mechanical properties are given in Table I, the broken test pieces were sectioned for metallographic examination. Nothing particular was found in the test pieces heated for 25 h at 200°C, but in the as-received test pieces small cracks were found near inclusions, or rather near the spots where the inclusions were embedded. The field in Fig.8 corresponds to a location in the centre of the fracture about 0·060 in. below its surface.

A single case also deserves description. Test piece G



8 *Cracks developing from inclusions at an angle to the direction of tension (tension parallel to the length of inclusions), unetched* ×50



9 *Unique fracture of a tensile test piece (Forging 3 from Table 1)* ×20

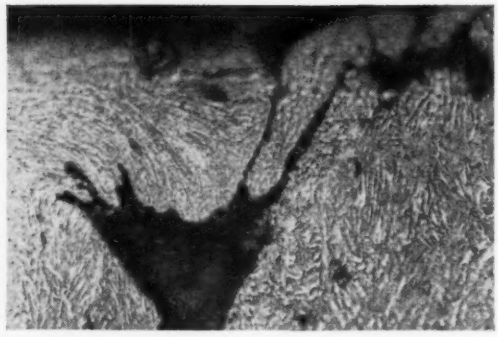
of forging no.3 from Table 1 was the only one which had a fracture as shown in Fig.9. All the mechanical properties of this test piece were typical except for reduction of area of 37·15% and elongation of 10%, which were responsible for the high variation figures quoted for forging no.3. The celluloid replica indicated that the fracture was intercrystalline with few cavities and some infrequent inclusions. Some of these cavities were deformed by the impact of the reaction, rupturing during the tensile test, but nevertheless retained some common features with Figs.5–8. Figure 10 shows an area with the cavities and the amount of distortion from the mentioned impact.

Odd fracture appearances connected with hydrogen cracks may not be typical enough for identification purposes, and, as the example of flakes show, may not be readily detectable in consequence of random occurrence.

GUIDED NOTCHED BEND TEST

The notched bend test may supply some information about hydrogen embrittlement if followed by microscopic examination. The bend test piece must be designed suitably as the notch severity influences the results as in the static fatigue test.[14] The bending requires good control and the guided bend test[15] appears suitable particularly when the female tool is designed with one adjustable side allowing economical application of a wide range of punches with different radii. The bend radius must be selected by experimentation because its magnitude controls the rate of deformation to a greater extent than the speed of the punch.

In the range of hardness 200–290 DPN and for



10 *Detail from Fig.9 after etching 2% Nital* ×750

thicknesses between 0·038–0·050 in., a bend radius of about 4 thicknesses and notch on the outside of the bend corresponding to Neuber's stress concentration factor 1·5–2·0 enables some discrimination of the behaviour during cracking.

The sheets which were plated with 0·0004 in. cadmium and subsequently heated for 6–8 h at 195°C were fractured in the notch, and formed straight cracks. When some plastic inclusions were present the cracks could have the appearance of those in Fig.11, but they had neither the tendency to spread in a plane perpendicular to the notch, nor to form configurations of intersecting cracks as shown in Fig.12. The cracks in the latter figure are strikingly similar to those found in service failures.

When the hardness of the material exceeds 350 DPN the selection of bend radii and stress concentration factors for the guided bend test becomes difficult, and the influence of the speed of the bending tool increases. A bend radius of 10 thicknesses is too small for 0·026 in. sheets to control the deformation rates at a stress concentration factor of 1·25. The accuracy of machining the notch introduces in this case another important variable in the stress concentration factor and the results scatter.

The notched bend test pieces crack mostly with an acoustic report which gives the signal to stop the test. Manually operated screw presses secure the best control of the speed of testing. To obtain conclusive results it is necessary to bend the test piece at least to an included angle of 135° before the cracking is heard. Cracking at smaller angles indicates excessive deformation speed, which must be decreased by changing to a larger bend radius and more patient slow bending.

CONCLUSIONS

In the light of present knowledge, the presence of hydrogen is responsible for impairing the steel's ability to withstand constantly stresses at levels determined by short-time static tests. The conditions for expelling hydrogen introduced during plating are not fully known, and there is an urgent need for establishment of inspection methods which could detect the amount of damage inflicted to the material by plating or unsatisfactory relief from hydrogen. The random occurrence of spots which nucleate hydrogen cracks aggravates the danger of missing defective parts or batches.

Notched tests appear to promise some help and sections through notched bend test pieces indicate that

11 *Crack in a notched bend test piece 224 DPN, cadmium plated, 0·0004 in. thick, heated 4 h at 195°C, unetched* ×50

12 *Crack in a notched bend test piece 232–236 DPN, cadmium plated, 0·0007 in. Not heat-treated after plating, unetched* ×50

hydrogen introduces a characteristic pattern of cracking. In thicker sections hydrogen cracks form characteristic fracture surfaces which may be readily recognized.

The nodular fracture of a tensile test piece may not be indicative on hydrogen embrittlement and the scatter in reduction of area figures prevents a conclusive assessment.

Study of sections through cracks and of fractures shows that the hydrogen cracks initiate at small discontinuities, most frequently metal-inclusion interfaces, and join until they find an outlet probably with the co-operation of the external stress.

The guided notched bend test followed by microscopic investigation of a section through the crack gives some promising results on materials up to 300 DPN hardness. In harder materials difficulties are experienced in maintaining low deformation rates, and more work is needed on accurately machined notches.

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The use of excess air during the ignition of a low-grade sinter mix

D. F. Ball

INTRODUCTION

IN THE SINTERING PROCESS it is often the case that the topmost layers are weaker than the main body of the sinter cake and thus contribute relatively less to the output of blast furnace sinter than the remainder of the sinter cake. These considerations gave rise to an investigation of the principal parameters affecting the strength of the topmost layers, and the results of this investigation were reported by Bates in 1957.* Of the results obtained, one which aroused considerable interest was the effect of excess air during the ignition upon the resultant strength of the topmost layer. It was shown that optimum ignition conditions exist when the gas volume withdrawn from the bottom of the bed is numerically equal to the volume of waste

SYNOPSIS

The effect of introducing excess air during ignition both through the ignition burner and by induced draught has been studied and the effect of this upon subsequent sinter strength determined. The extent of carbon solution during inert ignition has been investigated together with the effect of introducing excess air to inhibit this endothermic reaction. 1801

* H. Bates: *JISI*, 1957, **187,** 310–314.

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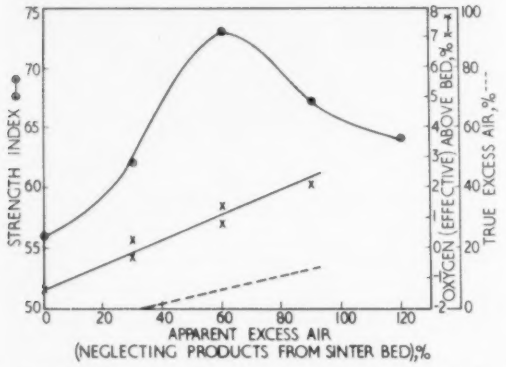
Mr Ball, who was formerly with the Ironmaking Division, is now Assistant in Chemistry at the University of Aberdeen.



1 *Excess air induced after burner, sinter strength, and gas composition* v. *apparent excess air*

products from the ignition gas plus a further volume equal to 0·6 of the air required to burn the ignition gas. It is interesting to consider to what extent this additional volume consists of volatile matter arising from the bed during the ignition period and to what extent the peak in the sinter strength *v.* 'excess air' curve is due to failure to draw in all the products of combustion at low volumes and a chilling of the edges of the cake at high values of excess air.

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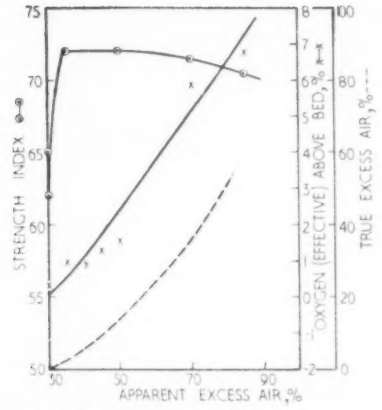
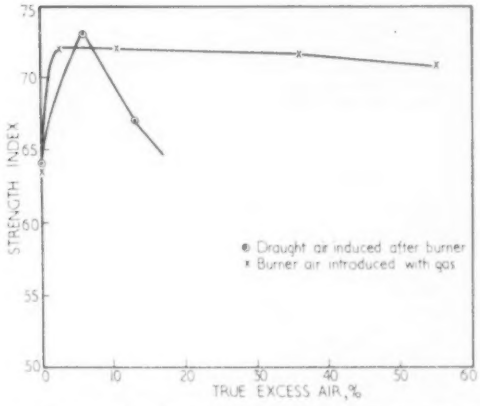
	Weight, lb	$\%H_2O$	$\%CO_2$ (dry)
Before ignition	44	10·7	11·2
After ignition	38	3·2	6·3

Calculations show that the waste-gas volume of 205 ft included 134 ft³ of true combustion products, 18 ft³ of CO_2, and 10 ft³ of H_2O ex-bed, leaving 43 ft³ of excess air or 36·5%.

The extent to which the excess air actually passes through the bed during ignition has been studied in a further series of tests. The gas composition above the bed during ignition has been determined by gas sampling from a manifold placed in the upper surface of the bed, all gas-sampling points being a distance greater than 3 in. from the edge of the bed. The results obtained have been expressed in terms of effective



2 *Excess air introduction through burner, sinter strength, and gas composition* v. *apparent excess air*



3 *Sinter strength* v. *true excess air deduced from gas analysis*

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$$\text{effective oxygen content } \% = \frac{4{\cdot}6 \times 0{\cdot}21 \times \%\text{ true excess air}}{5{\cdot}2 + \frac{4{\cdot}6}{100} \times \%\text{ true excess air}}$$

Figure 1 shows the relationship between strength index and apparent excess air based on the excess of waste gases over the theoretical products of combustion, and is in agreement with previous work. The effective oxygen content has also been included and used to derive a true excess air at the bed surface. It will be noted from Fig.1 that inert conditions occur when the apparent excess air is about 35%. The major proportion of this is CO_2 and H_2O from the bed and the remainder is excess air drawn down the edge of the bed.

Figure 2 shows the results of a parallel series of experiments in which various percentages of excess air were supplied to the bed through the ignition burner. Suction was adjusted to draw all products of combustion and excess air into the bed together with a volume equal to 30% of theoretical air to remove the volatiles evolved from the bed. In this case too, true excess air has been calculated from the effective oxygen content obtained by analysis of the gas reaching the upper surface of the bed.

It is clear from Fig.3 that the maximum sinter strength is obtained when the true excess air is very small (about 5%). It is also clear that excess air drawn in between the ignition hood and the bed, a high proportion of which is drawn down the edges of the bed chilling the sinter in this region, has an adverse effect on overall sinter strength. The extrapolation of these results to plant conditions is complicated by the fact that the ratio of the edge to surface area of the ignition hood is considerably less on a full-scale plant than on the 2 ft square experimental box. Thus the effect on total sinter quality of high excess air drawn down the sides of the bed will be less serious than that predicted by these experimental results. In the case where excess air is introduced through the burner (Fig.2) extrapolation of the results to plant conditions would appear to be justified, i.e. excess air introduced through the burner causes only a small decrease in sinter strength. It is doubtful whether the measurements are sufficiently accurate to prove whether slightly oxidizing or inert conditions are preferable.

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The pilot plant used for the second part of this work has already been described by Michard* and is now situated at the recently opened IRSID experimental station at Maizières-lès-Metz. The plant is equipped with infra-red recorders for the determination of CO_2 and CO in the waste gases from the sinter box, and in addition a paramagnetic oxygen recorder in the same line. The installation has the facility for measuring the secondary air volume entering the bed during ignition but not for measuring the burner primary air or the waste-gas volume leaving the bed. It is considered that the secondary air entering the bed during the ignition should be regarded as 'burner' air rather than draught air, since part is needed to burn the ignition gas and a part constitutes excess air introduced homogeneously over the bed surface. These experiments were carried out using a 6-cm (2·4-in.) deep bed in an experimental sinter box 30 cm (11·8 in.) square. A notable difference from the BISRA installation is that ignition is by commercial propane at a rate of 60 l/min (2·1 ft³/min). A prolonged ignition was selected in order to allow the recorders to stabilize and this gave a theoretical heat input of about 10000 Btu/ft² at a theoretical intensity of about 5000 Btu/ft²/min.

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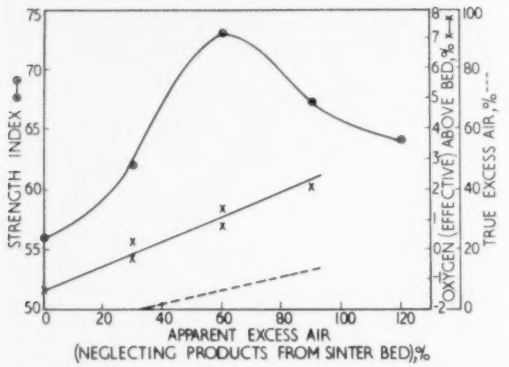

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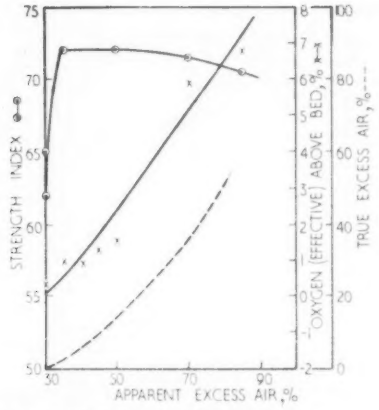

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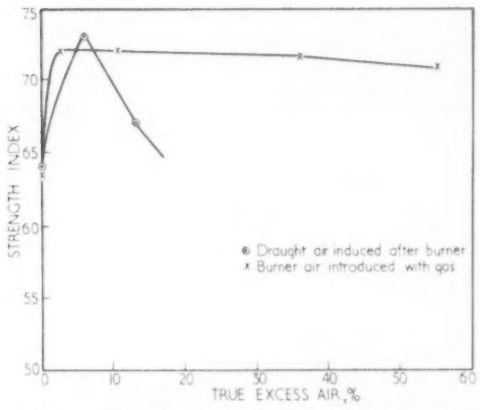

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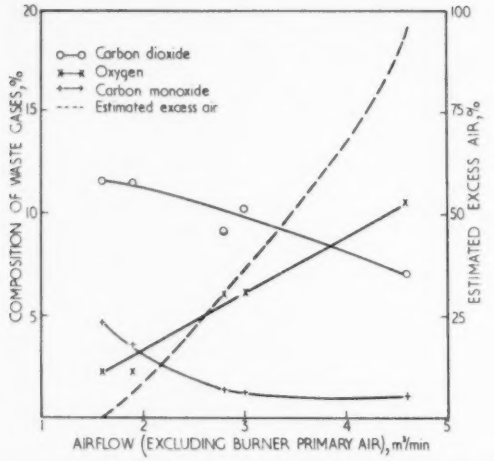
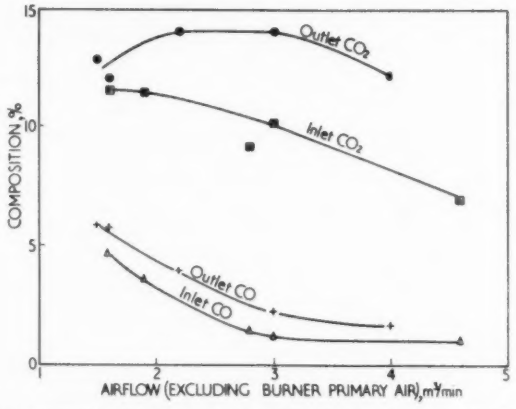


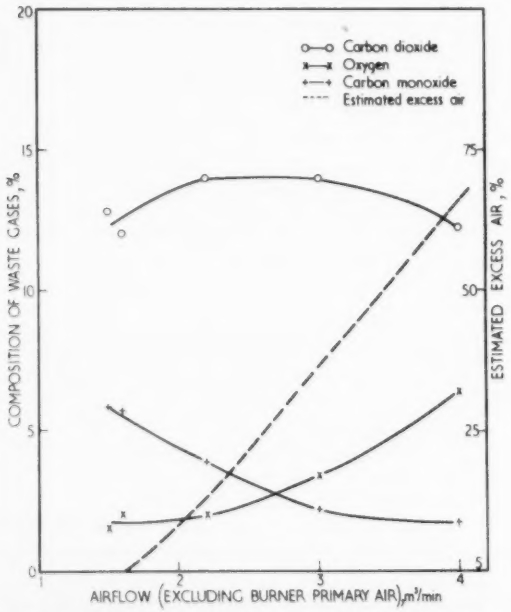
4 *Composition of waste gas and estimated % excess air when igniting crushed brick*



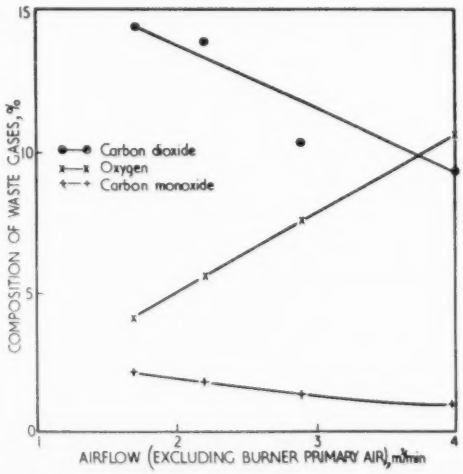
6 *Comparison of inlet and outlet gas composition when igniting a mixture of crushed brick + 5% coke*

experiments when the waste gas from the ignition layer was being analysed. It was considered likely that the efficiency of the burner with a gas requiring a high air volume would not be high and the results of the first series shown in Fig.4 indicate that it is impossible to eliminate carbon monoxide completely from the waste gases. The percentage excess air has been calculated from the percentage effective oxygen in a similar manner to that used for experiments with a burner using coke-oven gas. Figures 4–8 show the waste gas analysis for series (i)–(iv). Series (ii) was designed to show the extent of coke solution and the effect of introducing excess air when igniting an inert material. A comparison of the CO and CO_2 contents of the inlet gases during ignition of a mix of crushed brick and coke is shown in Fig.6. Series (iii) and (iv) were designed to show whether the introduction of an ore with high volatile content substantially modified the conclusions and a comparison of the waste-gas analysis with and without coke is shown in Fig.9.

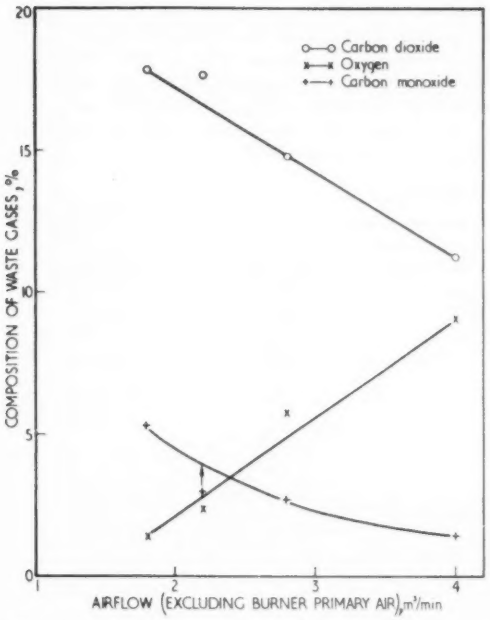
It is difficult to assess to what extent the additional CO produced during ignition as a result of carbon solution is due to the reaction $C+CO_2 \rightarrow 2\,CO$ or the water-gas reaction $C+H_2O \rightarrow CO+H_2$, but with the evidence available it seems reasonable to suggest that about 30% of the CO produced is due to the water-gas reaction. Figure 6 shows the increase in CO and CO_2 content when introducing coke to the inert mix. For inert ignition the CO content increases from 4·7 to 5·6 and if this 0·9%CO together with an estimated 0·3%H_2 were converted into CO_2 and H_2O this would result in about 3 – 4% more heat during the ignition period. As the true excess air increases, this effective loss through carbon solution decreases until at an airflow of 3 m³/min, equivalent to about 35% true excess air, the ratio $CO/(CO+CO_2)$ is $1{\cdot}0/(1{\cdot}0+4{\cdot}0)=0{\cdot}20$. This is the figure observed by IRSID in normal sintering operation on pilot and full scale and suggests that



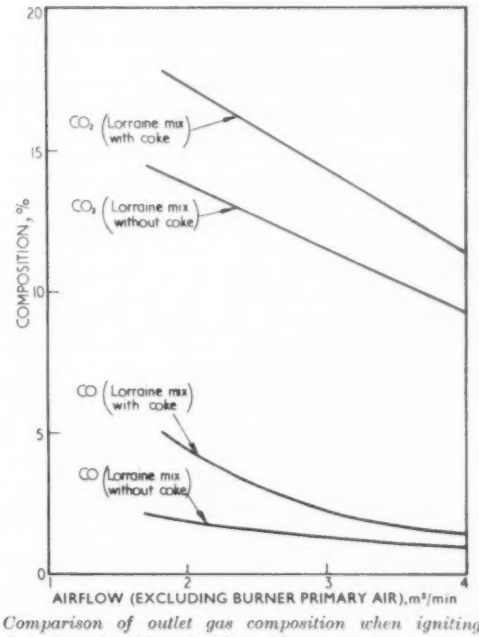
5 *Composition of waste gas and estimated % excess air when igniting crushed brick + 5% coke + 10% water*



7 *Composition of waste gas when igniting Lorraine ore + return fines only*



8 *Composition of waste gas when igniting Lorraine mix (4·5% coke)*


CO₂ (Lorraine mix with coke)
CO₂ (Lorraine mix without coke)
CO (Lorraine mix with coke)
CO (Lorraine mix without coke)
COMPOSITION, %
AIRFLOW (EXCLUDING BURNER PRIMARY AIR), m³/min

9 *Comparison of outlet gas composition when igniting a Lorraine mix with and without coke*

35% true excess air suffices to suppress any carbon solution brought about by the conditions of ignition.

A similar estimation using Fig.9, and taking into account the fact that the volume of waste gases is somewhat greater than the volume entering the bed, indicates that the heat loss under inert conditions is about 12–13% and that this diminishes until at a true excess air volume of about 55% the coke is utilized in a manner similar to sintering itself. It would appear that this rather higher value is partly due to a weakness in the method of interpreting the results. The waste-gas CO content for Lorraine mix without coke is considerably lower than for crushed brick, and furthermore the CO concentrations when igniting crushed brick and coke and Lorraine mix with coke are identical. It is, in fact, the lower CO concentration when igniting Lorraine ore alone, rather than the higher CO concentration in the waste gases when coke is present, which is responsible for the rather high figure of 12–13% heat loss through solution, and it is suggested that a value of between 5 and 10% is probably a more accurate estimation.

DISCUSSION

The results obtained would indicate that there are, in all probability, two opposing effects operating during ignition. With inert ignition there is some small loss of heat due to carbon solution and this is reduced by the introduction of excess air during the ignition period.

TABLE I Waste-gas volume, ft³

	Propane	Coke-oven gas	Blast-furnace gas
CO_2	4·8	3·7	16·5
H_2O	6·1	9·9	0·8
N_2	29·6	30·1	49·9
Approx. flame temp., °C	1900	1900	1450

Acting in the opposite direction, the introduction of excess air reduces the flame temperature and thus results in poorer heat transfer, so coke burning becomes essential if a temperature similar to that found during inert ignition is to be reached. It is the result of these two opposing effects which may be responsible for the small change in sinter strength when excess air is introduced through the burner.

It is worth considering whether the results obtained using a propane ignition can justifiably be extrapolated to cover ignition with coke-oven or blast-furnace gas. Table I shows the volume of waste products in ft³ for a thermal input of 4000 Btu.

It is considered that the results can be reasonably extrapolated on a qualitative basis for the case where ignition is by coke-oven gas since the waste-gas volume and flame temperatures are of similar order. Extrapolation of the results to blast-furnace gas needs considerably more care since introduction of excess air may reduce the flame temperature below that required for normal sintering. While coke burning during ignition may subsequently raise the temperature of the bed top to that required to sinter it, it is difficult to predict in this case that the introduction of excess air will not have an effect upon the resultant sinter strength.

It was shown by Bates (*loc. cit.*) that, while ignition conditions were less critical in the case of foreign ores, substantially similar optimum excess air conditions existed for foreign and home ores. It is considered that while the carbon solution figures determined for the ignition of a crushed brick–coke mix might well be similar to those existing during the ignition of a foreign ore mix, in general the extrapolation of ignition results from low-grade mixes to foreign ore mixes is not justified. Thus the use of excess air during the ignition of foreign ore mixes must clearly be the subject of a separate investigation.

CONCLUSIONS

It has been shown that the introduction of excess air through the burner during the ignition of a low-grade sinter mix results in little change in the subsequent sinter strength of the topmost layers. It is reasonable to believe that having taken due account of the optimum values for heat input and intensity reported by Bates a near optimum ignition of a low-grade sinter mix will result if attention is paid to the following factors: (*a*) sufficient air is introduced to the burner to ensure complete combustion, and (*b*) the suction is adjusted, first so that there is no loss in total heat input due to a proportion of the burner waste gases failing to enter the bed and, second, so that there is very little cold air drawn in at the edge of the igniter to chill the sinter mix at the edges.

Investigations of waste-gas analysis during ignition have indicated that coke solution reduces total heat input by about 5–10% during inert ignition, and that this reaction is inhibited by the introduction of excess air until when a value of 30–60% excess air is reached the coke is utilized as effectively as during normal sintering.

ACKNOWLEDGMENTS

The author is indebted to IRSID for granting facilities to carry out the latter part of this investigation and for permission to publish the results. Throughout these tests the author enjoyed the fullest co-operation and encouragement from the staff at the Station d'Essais, Maizières-lès-Metz.

APPENDIX

One volume of coke-oven gas requires 4·6 volumes of air for combustion and gives 5·2 volumes of waste products. If the true excess air is y% then from one volume of coke oven gas

$$\text{Total volume} = 5{\cdot}2 + \frac{4{\cdot}6y}{100}$$

$$\text{Oxygen} = \frac{4{\cdot}6y}{100} \times 0{\cdot}21$$

$$\%\ \text{oxygen} = \frac{\frac{4{\cdot}6y}{100} \times 0{\cdot}21 \times 100}{5{\cdot}2 + \frac{4{\cdot}6y}{100}}$$

$$\text{Therefore } \%\ \text{oxygen} = \frac{4{\cdot}6 \times 0{\cdot}21 \times \%\ \text{true excess air}}{5{\cdot}2 + \frac{4{\cdot}6}{100} \times \%\ \text{true excess air}}$$

Letter to the Editor

Coal-made iron

UP TO ABOUT 1943 there were still two ironmaking blast-furnaces in Scotland using coal as the heating and reducing agent. The general trend of blast-furnace design has been to make them taller and narrower in proportion and to push up the output rate in pounds of iron per square foot of hearth area as high as possible. This has necessarily meant a very tall blast-furnace to give the required time for the slow reducing and heat transfer reactions in the shaft, in spite of the rapid downward velocity of the solids. In turn this has made the requirements for a hard coke to support the weight of the burden and give a permeable bed more and more acute. The purpose of this letter is to consider the possibility of using what is now the cheapest reducing agent and heating agent in the UK, namely small non-coking coal, in the blast-furnace.

Obviously this requires reversing the whole trend of tall narrow blast-furnaces with a high output per unit of hearth area. Consider, for example, a simplified system consisting of three cubes, one on top of the other, of side L. In this case the surface area of the sides are 12 L^2 and of the bottom $1 \times L^2$, giving a total of 13 L^2, or if the bottom is regarded as fully insulated, only 12 L^2. The equivalent for a cylindrical shaft with the same cross-sectional area of L^2 and the same height of 3 L gives a surface area of the sides of $6\sqrt{\pi}\ L^2 = 10{\cdot}6\ L^2$, and the bottom will again be L^2.

If on the other hand we put the three cubes side by side horizontally, then the surface area of the sides is 8 L^2 and of the bottom 3 L^2. Thus the surface for heat losses and refractories on the sides is very much less than either of the other two models, and even if the area of the bottom is taken into account we still obtain a heat loss surface area appreciably less than the cylindrical shaft. If instead of calculating for simplified geometrical shapes, one takes an actual blast-furnace, e.g. the Queen Anne for which the figures are given by Elliott,* we reach the same conclusion, i.e. that we could have a blast-furnace with three times the cross-sectional area and in the form of a long narrow slot, 18 ft wide, 87 ft long, and 27 ft high, which would have exactly the same total volume as the Queen Anne furnace, namely 42400 ft³ but would have three times the cross-sectional area and a third of the height, and the surface area of the walls would be reduced from 6600 ft² for the Queen Anne to 5700 ft² for the slot-shaped furnace.

With such a furnace having three times the cross-sectional area if we wished to obtain the same output of iron per hour, the blowing velocity will be one-third as much, the time of dwell of the gases and of the solids in the furnace will be equal to the high narrow one, and the height will be one-third, so that the pressure drop in the vertical flow of the gases will be reduced to about $\frac{1}{27}$ of that in the present type of furnace. Very high velocity tuyeres could be used to give good penetration of the blast into the bed, but the main advantage would be that there would be very much less crushing effect of the weight of the charge, and a good blast distribution could be obtained merely by having a large number of tuyeres all round the long sides and the ends of the shaft. The charging arrangement would be similar to that on a coke oven, i.e. a car running along the top and charging through a large number of small bells.

The whole capital cost of the coke oven and blast-furnace plant would have to be considered in comparing it with the present arrangement, and even then the overall cost of the fuel would be appreciably less, so that this plant could be significantly less efficient than the present blast-furnace. This would occur because the volatiles in the coal would come off and enrich the blast-furnace gas at the top which would thus be a medium-grade producer gas of about 150 Btu/ft³.

However, if part of the purpose of the system is to produce a coal producer gas, it is not uneconomic to produce such a gas and to have cleaning arrangements for the tar as at present provided on the coke-oven plant. The higher calorific value gas would be very useful throughout an integrated works. The objection may be raised that it would be difficult to hold the brickwork in the shaft of the furnace, but this is surely a case for the use of the self-lining blast-furnace proposed by Archibald,† in which case there would need to be no bricks and the layers of the shelves would be filled permanently with a layer of fine ore and small coal which would act as a satisfactory lining.

Again, because the shaft is so much lower, the danger of scaffolding and of heavy slips would be much reduced. This is suggested as a possible line of thought for ironmaking in the future.

M. W. THRING — *Professor of Fuel Technology and Chemical Engineering, University of Sheffield*

* G. D. ELLIOT: *JISI*, 1955, **181**, 1–16.

† W. A. ARCHIBALD *et al.*: *ibid.*, 1957, **187**, 32–45.

Powder Metallurgy no.5

Powder Metallurgy, which appears twice a year, is the official organ of the Powder Metallurgy Joint Group. It is obtainable by annual subscription at 25*s* (post free) to non-members; members of The Iron and Steel Institute and The Institute of Metals may obtain it for an annual fee of 10*s* post free.

The following papers appeared in *Powder Metallurgy no.5*, which was recently published.

'*The rolling of copper strip from hydrogen-reduced and other powders*' by D. G. Hunt and R. Eborall (British Non-Ferrous Metals Research Association, London). Copper powders were rolled to form strip in a normal two-high mill. Satisfactory green strip was obtained from the low-density powder produced by hydrogen reduction from aqueous solution, provided that a mechanical method was used to feed the powder into the rolls. All the types of powder investigated required considerable further rolling after compaction, with at least two heat-treatments, to produce normal mechanical properties.

'*Some mechanical requirements of plant for the roll-compacting process*' by A. F. Marshall (BSA Group Research Centre, Birmingham). The paper is based on a survey of recent literature on the art of roll-compacting made for the purpose of producing criteria for use in the design of processing plant. After a definition of the duty required of such plant has been given, the type of mill necessary is discussed, and the various systems used for dispensing powder are considered in relation to the operational requirements. The process of roll compacting and the resulting strip conditions are discussed in relation to the variables in physical dimensions of plant and product. Certain criteria applying to the roll-compacting process are mentioned, and the wide variation in strip speeds employed by various investigators is noted. It is considered that roll loads, as given by some investigators, may be higher than those actually obtaining in practice, and some explanation of this claim is given. Finally, brief reference is made to the lubrication of the rolls or the powder during the compacting process and to subsequent processes including sintering, densification, and cold rolling.

'*Continuous compaction by cyclic pressing*' by C. Deibel *et al.* (Westinghouse Electric Corporation, East Pittsburgh, Pa., USA). A process recently developed produces wide, thick bars of unlimited length from powder, granular, or sponge raw materials by a cyclic pressing operation. The process can be adapted readily for laboratory study or for large-scale production. Many materials have been pressed by this technique, and in all cases compaction was similar to that experienced in conventional pressing. Work on the pressing, sintering, and subsequent working of various nickel powders and of a nickel–iron–molybdenum magnetic alloy has been carried out. Carbonyl nickel powder produces nickel strip of high quality. A high-permeability alloy containing 79% nickel, 17% iron, and 4% molybdenum can be made into strip with good magnetic properties by compacting the powders with the cyclic-pressing technique and then sintering and rolling the pressed bar into strip.

'*The formation of uranium and of beryllium alloys by the solid-state sintering of mixed elemental powders*' by J. Williams and J. W. S. Jones (Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berks.). Large volume expansions accompany the formation of binary alloys of beryllium with uranium, thorium, iron, copper, zirconium, titanium, and vanadium, and of uranium with aluminium, during the sintering of the mixed, cold-compacted elemental powders. No expansion was detected during the sintering of binary mixtures of beryllium with aluminium, silicon, and magnesium, or mixtures of uranium with zirconium, molybdenum, iron, nickel, manganese, and chromium. When it occurs, expansion is anisotropic, being greatest in the direction of compacting; the degree of anisotropy varies with the constituents and the composition of the alloys. In systems undergoing expansion, the volume expansion/composition graphs exhibit maxima. For a given system the magnitude of the maximum is a function of the shape of compact, the particle size of the powders, and the sintering time and temperature; the composition at which the maximum occurs is sensibly unaffected by these latter variables.

These experimental observations, together with those of other investigators, can be satisfactorily interpreted on the hypothesis that volume expansion is due to the formation of diffusional porosity during sintering.

'*Metal–ceramic mixtures*' by P. Murray (Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berks.). The present position regarding cermets, based on either oxides or carbides as the brittle phase, is reviewed. The outlook for oxide systems is to some extent disappointing, since little gain in strength has been found compared with the oxide itself. Oxide cermets do, however, show an intermediate improvement in thermal shock-resistance that is useful in a number of directions. Carbide cermets appear adequate for many high-duty applications so far as thermal shock-resistance is concerned, but improvements in their resistance to mechanical shock are still necessary. Recent work on ductile ceramics is also reviewed, and the importance of carrying out experiments at high strain rates is emphasized. Finally, suggestions are made for further work in the field of cermets.

'*A metallographic technique for ferrites*' by J. E. Hughes and S. Ratcliffe (Siemens Edison Swan Ltd, Harlow, Essex). A technique is described for the rapid preparation of ferrite specimens for metallographic examination by means of polytetrafluorethylene polishing laps impregnated with diamond.

'*Sintered stainless steel.* I: *The influence of alloy composition upon compacting and sintering behaviour*' by R. L. Sands and J. F. Watkinson (BSA Group Research Centre, Birmingham). A number of stainless-steel powders have been examined and their properties determined after various compacting and sintering treatments.The influence of alloy composition has been considered, and various conclusions are drawn.

'*Sintered stainless steel.* II: *The properties of stainless-steel powders sintered in dissociated ammonia*' by R. L. Sands and J. F. Watkinson (BSA Group Research Centre, Birmingham). Powders having compositions selected in accordance with the results of earlier work have been processed under conditions simulating industrial practice. The properties that can be obtained under such conditions are described.

'*Textures in beryllium and tubes extruded from consolidated powder*' by N. A. Hill and J. Williams (Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berks.). The textures in beryllium rods and tubes extruded from consolidated powder have been studied by X-ray diffraction techniques. The temperature of extrusion has little effect on the texture, but the extrusion reduction determines which of two main types of texture is developed in tubes. In low-reduction textures ($\leqslant 6:1$), the basal planes tend to concentrate parallel to the surface of the tube; in high-reduction textures ($\geqslant 12:1$), the basal planes still lie parallel to the extrusion direction, but tend to concentrate at angles ranging from 45 to 90° to the surface. A prism-plane fibre texture is present in all tubes. The deformation mechanisms possibly responsible for these textures are discussed.

'*The compacting of graphite and graphite–uranium–thorium–mixtures*' by D. T. Livey *et al.* (Metallurgy Division, Atomic Energy Research Establishment, Harwell, Berks.). Fine artificial graphite powders can be cold-compacted to give bodies of high density (~88% of theoretical), low permeability ($B_0 \sim 10^{-14}$ cm^2), and reasonable strength. Such powders, after vacuum annealing, will not compact. Die-compacted powder has strongly anisotropic properties, owing to a high degree of preferred orientation within the compact; this effect is less marked in hydrostatically compacted powder. Minor dimensional changes occur when compacts are annealed in the range 600–1 000°C.

The preparation of fuels by incorporation of fissile and fertile materials into graphite powder and cold compacting is described.

'*The continuous sintering of copper–lead to steel*' by P. G. Forrester and J. K. Beddow (The Glacier Metal Co. Ltd, Kilmarnock, Ayrshire). Bimetal strip consisting of copper–lead bonded to steel is produced by sintering uncompacted powder on to the steel, compacting by rolling, and resintering. The mechanism of the process is considered in the light of published work on liquid-phase sintering and of some experiments in which material at various stages of processing has been examined physically and metallographically. It is concluded that the process differs from normal liquid-phase sintering in that interparticle welding is brought about by the intermediate rolling process.

Discussion on '*The powder metallurgy of magnetic materials*'. A report on the discussion at the last meeting of the Powder Metallurgy Joint Group, held in London on 16 December 1959.

Iron and Steelworks Engineering
THE IRON AND STEEL ENGINEERS GROUP

The modern plate mill

M. F. Dowding, M.A., M.I.Mech.E., C. Sturdy, M.A., A.M.I.Mech.E., and A. A. Thomas, M.A., A.M.I.Mech.E.

SYNOPSIS

Present-day requirements of metallurgical specification and dimensional tolerance have led to the introduction of new equipment in recent plate mill installations. Problems set by customer requirements, and methods of achieving the necessary characteristics in end products are discussed in this paper. Questions usually asked by steelmakers and the answers given by plant builders are considered. Finally, some general conclusions are drawn.

1819

METALLURGICAL CONSIDERATIONS OF ROLLING PLATE

Products and qualities

The materials plate mills are likely to be called upon to roll are as follows:

(i) *Rimming steels* These are low-carbon low-manganese steels, not treated with deoxidant, which are used when particularly good surface is required for general constructional plates. The material is also used for direct rolling of plates from ingots for the same end products.

(ii) *Semi-killed steels* Similar to rimming steels but partly de-oxidized by addition of aluminium or other de-oxidizing agent. Used for general constructional plates.

(iii) *Fully killed or stabilized steels* Because of the more completely de-oxidized state, higher carbon and manganese contents are possible. This steel is used for the production of better quality plates, e.g. boiler plate.

(iv) *Notch ductile steels* (Reference to BS.2762: 1956 for notch ductile steel, grades ND I-IV) Low carbon (0·10–0·20%) and high manganese (up to 1·5%), to prevent brittle failure of weldments. This steel is used for ship's plates in welded ship construction and all plates for weldments where weld strength is important. It is essential for all plates destined for use in low ambient temperatures.

(v) *Alloy steels* Low-alloy steels such as 'Corten' containing nickel, copper, and chromium additions, and 'Fortiweld', a high-strength weldable plate, are used for applications where higher yield strength is required.

(vi) *Stainless steels* Stainless steels are used for applications requiring either high hot-strength or anti-corrosion properties, or a combination of the two.

Influence of quality on manufacturing process

Heating The following are the recommended reheat temperatures before rolling:

Quality	Reheat temperature, °C
Mild steel (rimming, semi-killed, stabilized, and notch ductile)	1250–1350
Low-alloy steels	1250–1300
Higher-alloy steels	1250 max.
Austenitic stainless	1200–1250

The recommended finishing temperatures for the same qualities are as follows:

Quality	Finishing temperature, °C
Mild steel (rimming, semi-killed, stabilized, and notch ductile)	850–950
Low-alloy steels	850–950
Higher-alloy steels	800–900
Austenitic stainless	1000–1050

It should be noted that

(i) special attention has to be paid to the reheat temperature to limit grain growth and overheating in alloy steel, (ii) the range of temperature for rolling stainless steel is very narrow, and (iii) the temperature at which the plate is transferred from the roughing to the finishing stand of a two-stand mill is not critical but depends upon the finishing temperature required.

Notch ductility

Much of the attention focused on the effect of finishing temperature on mechanical properties is the result of brittle failure in welded constructions. The quality to resist this type of failure is termed notch ductility and is measured by subjecting notched specimens to impact and locating the temperature at which the fracture changes from ductile to brittle.

Main factors influencing the notch ductility of plate are: (*a*) chemical analysis, (*b*) finishing temperature, and (*c*) ferritic grain size.

Chemical analysis The British Standard specification laying down the minimum Charpy impact figure required allows a wide range of analyses to be employed. Many UK manufacturers have taken advantage of this and used a high manganese content, but if the finishing temperature can be adequately controlled it would be more economical to use lower manganese

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The authors are with Davy and United Engineering Co. Ltd.

steels giving the same quality. This practice has been adopted by some plants.

Finishing temperature Control of finishing temperature and consequent refinement of grain appreciably lowers the Charpy transition temperature and some plants use a controlled finishing temperature and a stabilized steel for high-quality plates. For top qualities, normalizing is generally specified. Normalizing has no effect on weldability, which is a function of thickness, analysis, and welding technique. Thick plates have a self-quenching effect on welding so that the welding technique should then consist of a number of light welding runs. The ND series of steels are designed specifically to meet the requirements both of notch ductility and weldability.

Ferritic grain size It has been found that control of the temperature to near to the Ar_3 change point (i.e. the temperature at which ferrite crystals begin to form from austenite) greatly increases the notch toughness. The ferritic grain size can be controlled in two ways: (*a*) by the addition of an austenitic grain refining deoxidizer, e.g. aluminium; (*b*) by refinement of the grain by normalizing.

Finishing and coiling temperatures

Rolling of the plate below the Ar_3 temperature can be detrimental under certain critical conditions. If a small amount of work is carried out, at about 2–3% below the Ar_3 temperature, recrystallization can occur at temperatures below the Ar_3 temperature, owing to the internal strain of the system, and rapid grain growth can occur. This phenomenon is particularly noticeable in coiled plate, where coiling itself can introduce the critical conditions. The method of overcoming this fault is control of the finishing temperature to near the Ar_3 point and coiling at slightly below the Ar_1 point.

This is confirmed by Dr Ball, whose metallurgical opinion was consulted by Cartwright and Dowding when preparing their paper.* For low carbon steels Ball gives 1650°F (900°C) as an optimum finishing temperature and 1200°F (650°C) as a maximum coiling temperature.

Edge rolling

Edge rolling is not essential when rolling from parallel-sided slabs except in the case of austenitic stainless steels and similar high alloys where early edge rolling inhibits the danger of bursting.

Transverse properties

Boiler plates which invariably come under the fully killed mild steel category should preferably be cross-rolled to equalize as far as possible the longitudinal and transverse properties. Cross-rolling to a minimum of 25% of the total reduction appears to have the desired effect, but this minimum cannot yet be completely confirmed. Equidirectional properties and microstructure cannot, however, be achieved without equal two-directional rolling through to the finished size, and this is, of course, impossible where long plates are being rolled. Microstructure and cleanness also influence the transverse properties. Microstructure is discussed under the separate heading 'Banded structures' but the effect of inclusion or cleanness on banding and transverse properties is worth noting.

During rolling, the inclusions are drawn out into thin pencils or, alternatively, thin plates where cross-rolling is undertaken and the resulting striae are nuclei for crystallization. Crystals therefore tend to grow in the direction of the inclusions and in unfavourable conditions large grains occur. The overall effect is twofold, resulting both in low ductility and impact in the transverse direction, due to preferential fracture along large grain boundary faces and along the inclusions.

Banded structures

The term does not appear to have been clearly defined, and is generally used to indicate either of two types of microstructure found in rolled plates, those due to finishing at high and low temperatures respectively.

Banding due to finishing at high temperature
The primary initiation of this type of banding is crystal growth due to grain boundary migration of the austenite at temperatures well above the upper critical temperature. Large austenite grains are formed and the resultant ferrite grains are massive, and oriented in the same direction as the original austenite, i.e. in the direction of rolling. Furthermore, non-metallic inclusions act as nuclei for the formation of ferrite crystals and, as these are in the form of thin pencils, in the direction of rolling. The resultant ferrite grains are banded.

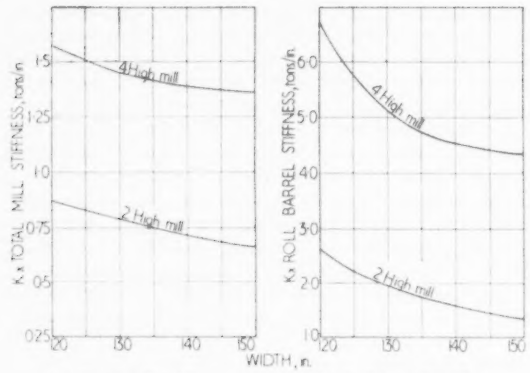
The condition is, of course, aggravated by slow cooling, since this causes a longer time at the high temperature and therefore larger austenite grains, and because slower cooling through the transformation range results in the formation of coarse pearlitic structures.

Banding due to low finishing temperatures
As a result of plastic deformation in the rolling direction of already transformed ferrite grains, recrystallization of the remaining austenite can only occur within this pattern, and the final structure consists of fine-grained ferrite crystals oriented in the rolling direction in the form of broken ferrite bands.

Methods of minimizing banded ferrite structure
The gross banded structure caused by finishing at high temperature is difficult to remove once crystal growth has taken place, and, although it is possible to improve the structure by thermal treatment, long and costly heat-treatment cycles are involved. The method of eliminating this type of structure is to control the finishing temperature to near the upper critical temperature of the steel, and ensure cooling in free air to below about 400°C. In practical terms this means the provision for holding plates between roughing and finishing stands to ensure correct finishing temperatures, and a sufficiently large cooling bank to avoid piling above about 400–500°C.

Prevention of banding due to low finishing temperatures can obviously be minimized by controlling the finishing temperature. Any banding due to finishing cold can be broken up to some extent by normalizing. It must be appreciated, however, that a normalizing

* W. F. Cartwright and M. F. Dowding: *JISI*, 1958, **188**, 23–35.



(*a*) Total mill stiffness (*b*) Roll barrell stiffness

1 *Relative stiffness of 2-high and 4-high mills for various roll-barrel widths*

treatment merely breaks up the ferritic crystal structure, and during cooling recrystallization of ferrite occurs on nuclei oriented in the direction of rolling. The overall effect is smaller grains of ferrite which have a less banded appearance mainly because of size. This treatment produces improved transverse impact properties as more crystal faces are presented to the direction of fracture. Considerable work must be done at the finishing temperature to ensure a fine-grained structure. This has been expressed as at least 10% reduction near to the final temperature.

SOME QUESTIONS AND ANSWERS ON PLATE MILLS

Ingots and slabs

1 *Should one plan to roll direct from ingot or from slabs produced from a slabbing mill?*

A slabbing mill, if it can be afforded, is desirable. Rolled slabs give better surface and better yield. Ingots for such slabs can be heavier and the range of sizes less than for direct plate rolling. The capital cost of a slabbing mill can only be justified if high outputs are required or if it can be used for feeding more than one mill.

2 *What is the range of slab sizes normally accepted today?*

Continuous reheat furnaces are currently being installed for the following slab sizes:

TABLE I 4-high plate mill roll sizes

Company	Roll barrel width, in.	Roll dia., in. Work	Back-up	Duty
A	120	36	54	Finishing
B	132	38	56	Finishing (plate) Roughing (hot strip)
C	132	38	60	Single stand
D	132	39	72	Single stand (170 in. wide roughing mill after conversion)
E	150	39	60	Intermediate
F	150	36½	60	Finishing
G	150	39	63	Finishing

Thickness	*Length*
Minimum 5 in.	Maximum about 10–12 ft
Normal 12 in.	Minimum about
Maximum 18 in.	4 ft 6 in.–5 ft 6 in.

3 *What are the slab and ingot problems associated with heavy, thick, plates?*

The main problem is yield, particularly where weldability is required. Large ingots are subject to considerable segregation which may render part of the plate unweldable. The finished plate structure may not be very good, as the rolling action does not penetrate right through. There is also the danger of over-rolling the edges. The net result is a yield of only about 50% so that a 20 ft × 10 ft × 5 in. plate would require an ingot of 80000 lb. Some over-rolling could be eliminated by a vertical edger, but the problem is essentially metallurgical and the only solution is to use smaller plates welded together.

4 *What slab handling, scarfing, and feeding arrangements are required?*

Using continuous furnaces and larger slabs poses problems similar to those in modern wide strip mills and the same solutions apply.

Slabs are received from the slabbing mill in piles, cooled, separated for inspection and scarfing, re-assembled into piles, and delivered to the slab depilers on the ingoing side of the furnaces. These deliver them singly to the furnace entry table from which they are pushed into the furnaces.

Heating

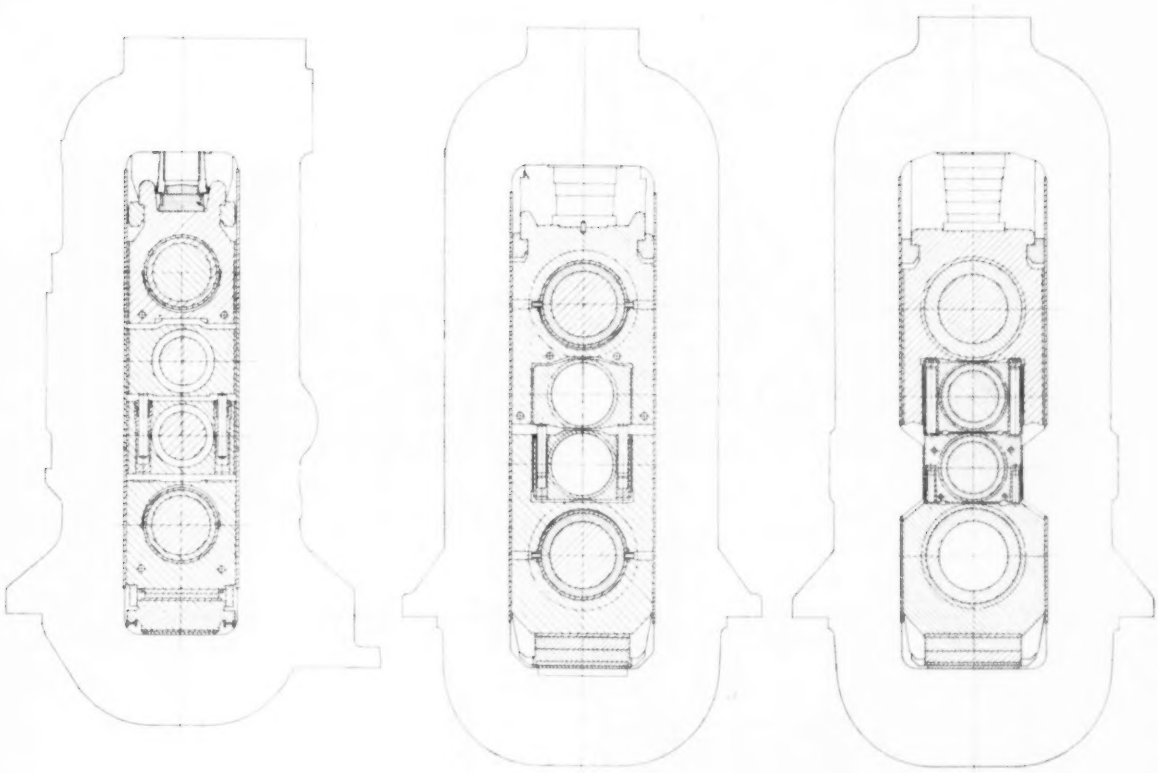
5 *Should continuous furnaces, soaking pits, or in-and-out furnaces be installed?*

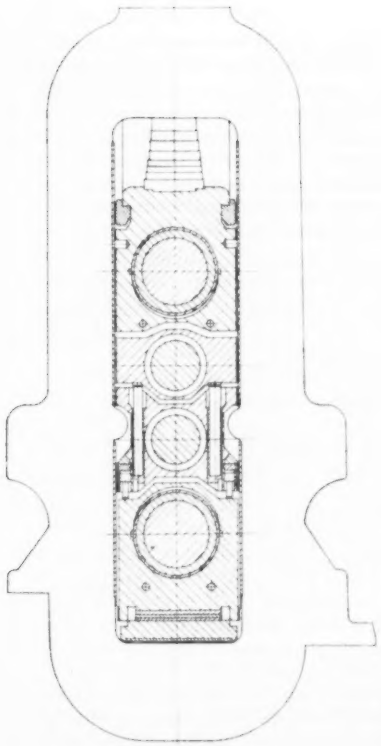
This depends on the order book pattern and the output required. Present-day outputs are high

TABLE II Typical modern plate mill main drive ratings

Mill Nominal roll width, in.	Work roll dia., in.	Type	Ft/min Base speed	Ft/min Top speed	Drives rms rating, hp	rev/min Base speed	rev/min Top speed	Cut-out torque, ton-m	Physical arrangement
160	38	4-high single stand	350	900	8000	35	90	492	Twin motor (DA)
126	42	2-high roughing	440	880	4600	40	80	246	Single motor (SA)
150	39	4-high intermediate	410	1025	9200	40	100	492	Twin motor (SA)
150	36·5	4-high finishing	435	1090	9200	40	100	492	Twin motor (SA)
150	46	2-high roughing	482	Limited to 720	6000	40	80	321	Twin motor (SA)
150	39	4-high finishing	408	1020	8000	40	100	427	Twin motor (SA)
132	39	4-high single stand	460	815	10360	45	80	492	Twin motor (SA)
144	38	4-high single stand	400	1000	10000	40	100	492	Twin motor (SA)
98	32	4-high single stand	375	750	5000	45	90	240	Single motor (SA)
90	27	4-high intermediate	300	535	3650	42	75	183	Single motor (SA)
90	27	4-high finishing	390	530	2650	55	75	100	Single motor (SA)
86	37	Reversing rougher and plate mill	485	1160	7000	50	120	300	Single motor (SA)

SA single armature, DA double armature.





2 *Alternative roll balance systems*

and can be met only by installing continuous reheat furnaces. These furnaces, however, require careful scheduling of slab thicknesses and lengths, but with high outputs and careful scheduling a suitable slab programme can be achieved.

If, of course, plate has to be rolled direct or from slab ingots, soaking pits must be used.

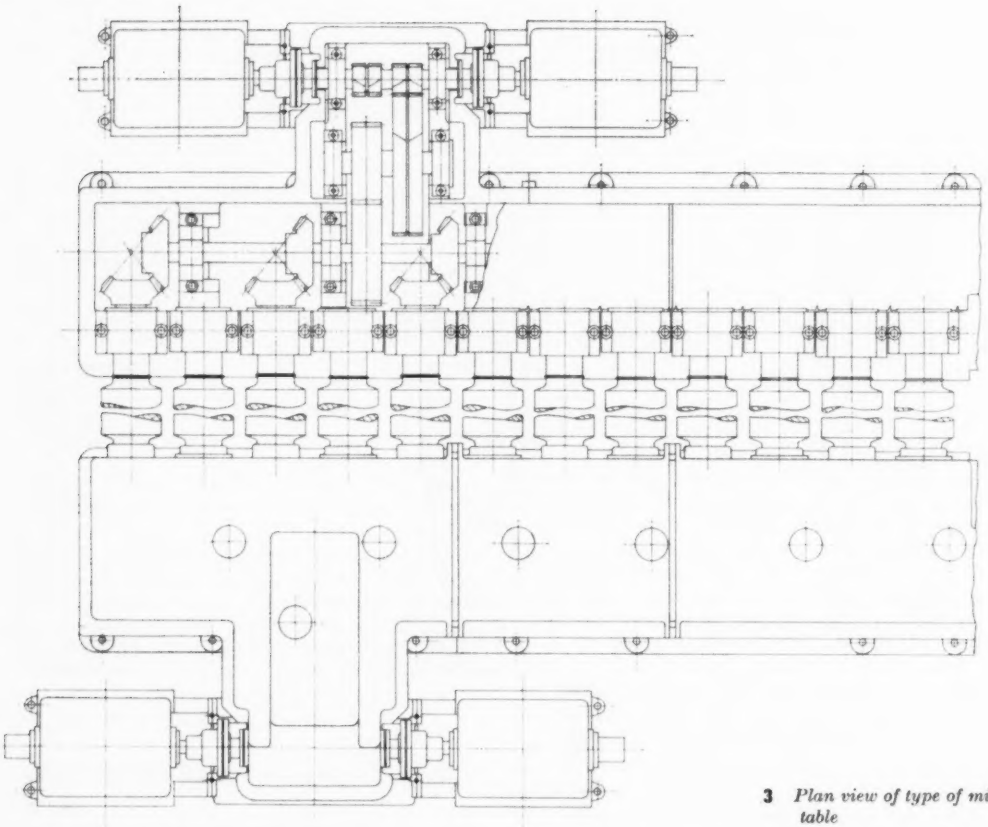
If the output required is not large or the order book contains a large diversity of slab size and steel quality, in-and-out furnaces may be the right solution. They are also useful as an adjunct to continuous furnaces to deal with off-cuts and small orders.

6 *How should continuous furnaces be scheduled?* Adjacent slabs should not be too different in thickness, or the smaller slab may cock up and jam against the furnace roof.

The efficient operation of furnaces at their rated capacity depends upon good hearth coverage. If too many short slabs are pushed at one time, large areas of the hearth will be uncovered, with consequent loss of heat. Different steel qualities require different soaking times, and

TABLE III Screwing speeds on some recent and projected mills

Mill duty	Screwing speed, in./min
Roughing	30–60
Intermediate	12–30
Finishing	12–30
Roughing and finishing	30–60



3 *Plan view of type of mill table*

therefore quality changes in the furnace burden should, if possible, be infrequent. Occasionally dummy slabs may have to be pushed to cushion the effect of an abrupt quality change. The problems associated with scheduling continuous furnaces can be eased by using two or three furnaces at once.

Rolling mills

7 *What provision should be made for scalebreaking and for descaling?*

There are three methods of descaling:

(i) a 2-high mill which can also be made to do a limited amount of reduction and can be made to take broadsiding passes

(ii) a heavy edger to break the scale; this enables the slab stock range to be reduced slightly since fewer widths need to be held

(iii) a descaling box having high-pressure water jets suitably baffled is sufficient to remove scale provided that the furnace operation is maintained in optimum condition.

Descaling sprays should, of course, be fitted on the units described under alternatives (i) and (ii). The pressure at the pumps should be 1500 lb/in^2, and in the case of a 2-high scale-breaker it is advisable to have the sprays located at each side of the stand. For descaling during rolling, similar sprays should be located at each reduction mill. Top and bottom sprays should in all cases be provided, and they should be located if possible less than 12 in. from the plate. This poses problems for the top sprays which have to be arranged to move with the top roll and heavily shrouded to prevent damage from upturned plates. Descaling sprays are best operated manually, not automatically. The operator can then use them at his discretion, depending upon the amount of scale present and the temperature of the piece.

8 *How many stands should be installed?*

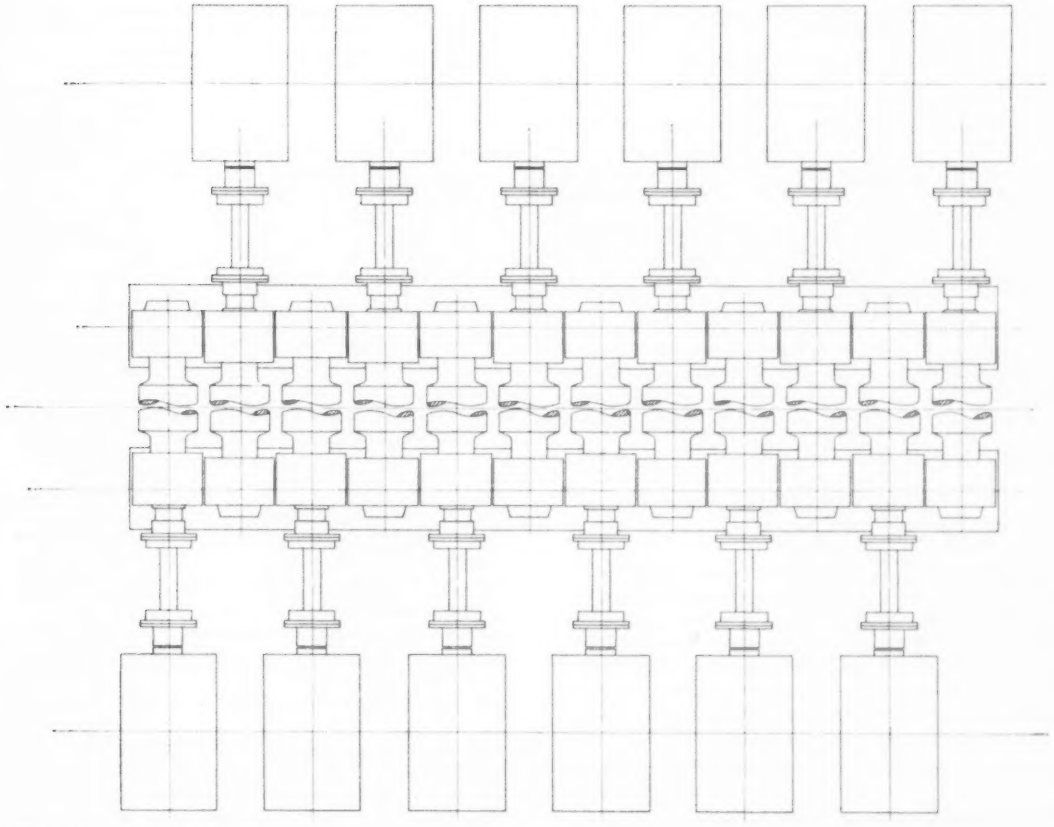
It depends on the output required. Broadly speaking, for 10-ft mills the following applies:

Layout	Annual output, tons
Single-stand 4-high	500000
2-high rougher, 4-high finisher	750000
4-high rougher, 4-high finisher	1000000

If the first mill is a 4-high, an adequate descaling station must be installed in advance of it. If it is a 2-high its duty can be that of a scalebreaker.

9 *On a 2-stand layout, at what thickness should the piece be passed from the first to the second stand?*

This should be such that both mills are fully utilized and any piece takes the same time for its reduction on each stand. If controlled temperature rolling is being practised the piece should be rolled in the roughing stand until it is about 180% of the finished required thickness. At this point it is held between the two stands and allowed to cool to a predetermined temperature, after which the requisite number of finishing passes are taken



4 *Plan view of type of mill table*

so that it reaches gauge at the final required temperature.

10 *Is a 4-high mill essential as a finisher?*
Figure 1 demonstrates the relative stiffness of the 2-high and 4-high mills for various roll barrel widths. Wide plates from 2-high mills sometimes show as much as 30 thou. centre whereas it is exceptional to find a centre more than 5 thou. on a plate rolled on a modern 4-high mill. It is generally accepted, therefore, that the 4-high mill, capable of taking heavy reductions and producing plate with close dimensional tolerances is the right mill to install at the finishing position, in the light of increasingly rigid market requirements.

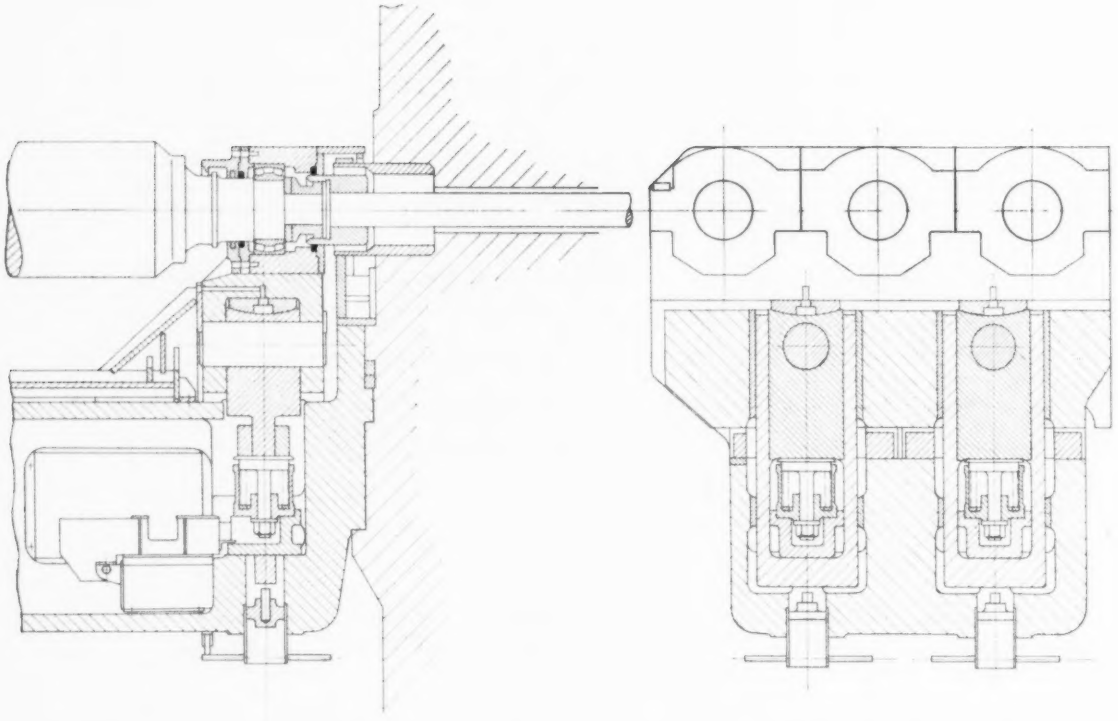
11 *What are the work roll and back-up diameters now being installed?*
Table I gives a list of the roll sizes of recent and projected mills of differing widths.

12 *What powers are installed on modern plate mills?*
Table II gives motor powers associated with recent installations. Adequate torque must be available to give full benefit of heavy drafting possible on 4-high mills.

13 *What features are desirable in a roll balance system?*
Balance must be positive and all clearances firmly taken up. The minimum number of hydraulic connexions to the chocks is desirable. The top back-up chocks should be supported from a central cylinder located in the top housing distance piece. The work rolls on a reversing mill should be balanced in such a way that the balancing force presses both the top and bottom work rolls against their respective back-up rolls to avoid slipping during reversal. In considering the various methods that have been evolved to do this, simplicity and fast roll changing must always be borne in mind. Figure 2 shows various alternative arrangements that have been developed.

14 *How often is roll changing necessary and what is the best method of doing it?*
On a 2-stand set-up the finishing-mill work rolls are changed about every 2000–2500 tons. On a single-stand mill the work rolls will have to be changed about twice as frequently. The best way of changing work rolls is by porter bar. On very wide mills the counterweight may well have to be motorized. By this means, work rolls can be changed in about half an hour.

The best method of changing back-up rolls is by roll change sledge, or where the buildings and cranes are strong enough, by C-hook. Where more than one similar stand occurs in the same layout, a portable roll change rig may be employed to avoid needing a separate rig for each stand. On exceptionally wide mills over about 150 in., a porter bar for the work rolls may not be practic-



5 *Typical feed roller arrangement, using springs*

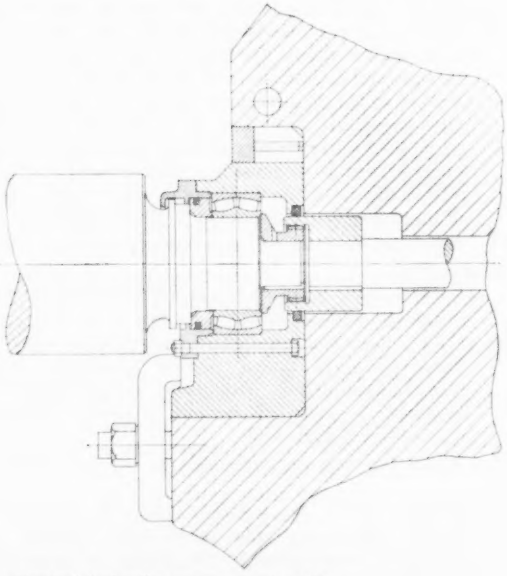
able. In this case the work rolls may be withdrawn on the bottom back-up roll on the roll change sledge, and changed by crane. It is not thought worthwhile for a separate sledge for the work rolls to be provided.

15 *What are the best screwdown speeds?*
This depends upon the programmes being rolled and the position of the stand in the layout. Table III shows the screwing speed on several recent and projected plate mills.

16 *Should edgers be installed?*
Except when rolling direct from the ingot, the edging mill is an overrated luxury. When rolling from the ingot the yield ingot to plate is improved by about 3%. When rolling from slab to plate an edger only improves the yield by about ½%. It may be necessary to install an edger if a lot of stainless steel is being rolled, to give enough edge work to prevent edge cracking. If an edger is installed, it should be on the ingoing side of the mill where it helps to feed the piece into the bite; since the ingoing speed more nearly approximates to the main mill motor speed, speed matching is easier.

17 *What is the best method of turning the slab round for broadsiding?*
It should be by conical roller table which can turn the slab very quickly close to the mill bite, and to a certain extent is self-centring. Turning buttons are cheaper but require operational skill and time to get the plates central for lifting.

18 *What type of mill table is recommended?*
Either lineshaft drive or individual drive, both



6 *Typical feed roller arrangement, solid*

TABLE IV Typical yields from a modern plate mill

Plant	Ingot/slab, %	Slab/plate, %	Ingot/plate, %
1 Continuous strip mill	88–90	93	83·7
2 (*a*) 2-high mill	87·5	77	67
(*b*) 4-high mill	87·0	80	70
3 2-high and 4-high mill	91 (semi-killed)	81·0 (thin plate) 83·5 (thicker plate)	73·7 76
4 Semi-continuous plate and strip mill	87–88	80–81	70·5
5 4-high	Rolling direct from ingot	Killed steel Rimming steel	69 75·5

TABLE V Typical tolerances produced from 4-high mills

Plant	Thicknesses Up to 0·4 in. (10 mm)	10–25 mm (0·4–1 in.)	Over 25 mm (Over 1 in.)
A 2-high–4-high	±0·012 in.	+0·016 in. −0·012 in.	+0·020 in. −0·012 in.
	length and breadth		
B 4-high single stand		+0·010 in. −0·000 in. } width	+0·012 in. along plate 65 ft long
British normal tolerances	up to ⅛ in. +10%, −0% (+0·012 in.)	⅛ to ¼ in. ±5% ±0·006 in. ±0·012 in.	over ¼ in. ±2½% ±0·006 in. to 0·050 in.

types with heavy cast steel or fabricated frames. Figures 3 and 4 show the two types in plan view. With double drives (conical rollers, alternate rollers driven from alternate sides) the table cost, mechanical plus electrical, of the two types of installation is similar.

19 *How should the feed rollers be driven?*
The design of the feed rollers, their drives, and method of mounting, is of critical importance to the proper and reliable functioning of the mill. Gear or chain drives should be avoided, as they do not live in an area where scale ingress aggravated by high-pressure descaling water causes rapid wear or choking of working parts. Individual drives from outside the housings should be installed, the drive shafts passing through the housing post.

The rolls themselves should be mounted in roller bearings located in rugged frames securely locked on to the housings. Breast rollers carry heavy shock duty and for this reason spring mounting is often used. Two typical arrangements, one using springs and one solid, are shown in Figs.5 and 6.

20 *What is the latest development in sideguard design?*
These should be rugged, self-centring, and arranged for short stroking. They must be long enough and adequately sited to keep even the largest rolled plate straight and in the centre of the mill.

21 *What yields can be expected from a modern plate mill?*
Table IV illustrates typical figures.

22 *What tolerances can be expected from a modern mill?*
Table V shows typical tolerances produced from 4-high mills.

A modern 4-high mill will give centres well within all the tolerances shown in Table V, and end-to-end tolerance should be less than 0·015 in. even on 120-ft rolled plates.

23 *What is the longest plate that can be rolled?*
This depends on the thickness. As a rough guide the following should be possible:

⅛ in. thick	up to	60 ft
¼ in.	,,	90 ft
½ in.	,,	120 ft

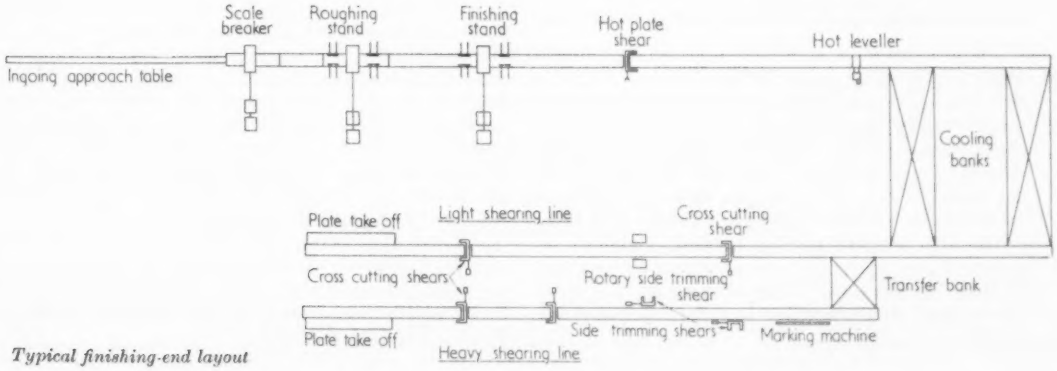
Thereafter slab size, reheat temperature, and finishing temperature all tend to reduce the length that can be produced. Shipped lengths depend upon the order book requirements and shipping facilities. British transport facilities normally allow maximum dimensions of 40–60 ft. From the yield standpoint two or three 40-ft plates should be rolled from one slab at ½–1 in. thick.

24 *What is the thickest plate that can be side trimmed on a rotary shear?*
Not thicker than ¾ in. or 20 mm. The shear may cut above this thickness but the edges are such that they are not suitable for welding without considerable treatment.

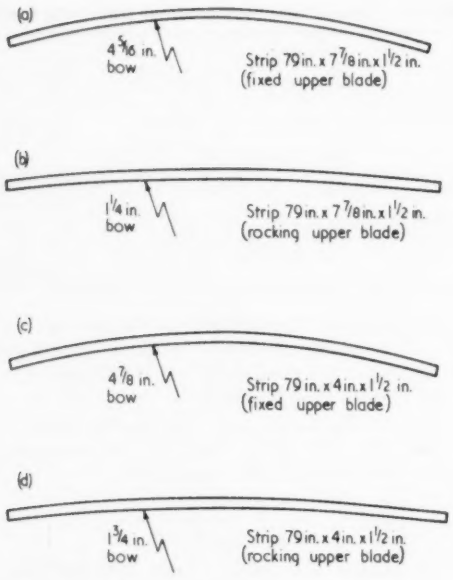
Finishing equipment

25 *What layout should be adopted?*
This must be decided against the following factors: (*a*) output; (*b*) sizes, thicknesses, and specifications in the order book, and (*c*) rolled length and width.

Particular attention should be paid to scrap handling as 20% of all rolled plates eventually go back to the melting shop as scrap. It is usual to divide the finishing end into a heavy and light shearing line. A typical layout is shown in Fig.7.



7 *Typical finishing-end layout*


(a)
4 5/16 in. bow
Strip 79 in. x 7 7/8 in. x 1 1/2 in. (fixed upper blade)
(b)
1 1/4 in. bow
Strip 79 in. x 7 7/8 in. x 1 1/2 in. (rocking upper blade)
(c)
4 7/8 in. bow
Strip 79 in. x 4 in. x 1 1/2 in. (fixed upper blade)
(d)
1 3/4 in. bow
Strip 79 in. x 4 in. x 1 1/2 in. (rocking upper blade)

8 *Rocking blade shears*

26 *How many levellers should be installed?*
A heavy hot leveller to deal with all thicknesses from $\frac{1}{2}$ in. up to 2 in. can usually deal with most of the output. It may be necessary to normalize all thinner plates, in which case another leveller must be installed after the normalizing furnace. Cold levellers should be installed at the end of both heavy and light lines to get best quality and flattest plates, and for reclamation.

27 *What sort of cooling bank should be used?*
The heavy cast-iron bed with chains is satisfactory although some operators think it scratches the plate. Chain skids working on roller-type banks reduce this risk but require more maintenance. In all designs the plate should be well supported and not allowed to sag while hot. Turnover arms capable of presenting the plate either side up to the exit tables should be included in the bank.

28 *Where should the plate be marked?*
Either on the bank or on the outgoing tables, according to the operators' preference. If it is done on the outgoing table, room must be left so that a marking machine can be used to reduce the manning.

29 *What sort of shear should be used?*
For cross-cut on both lines, and for the side shears on the heavy line, rocking blade shears give less shear bow, better shaped plates, and scrap (Fig.8). They are more expensive but are worth the money. Scrap choppers and conveyors should be included. On the light line a rotary side trim shear with a slitting head behind it should be installed, in addition to two cross cut shears, one in front of the rotary side trim shear to give a square end, and one after to cut to the ordered length.

Instrumentation

30 *What developments have occurred in the instrumentation of plate mills?*
The following instruments have been developed and are working satisfactorily in several plants: (*a*) γ-thickness gauges, (*b*) width and length meters, (*c*) loadmeters.

The γ-thickness gauge will measure all plate thicknesses up to 2 in. The widthmeter can be installed to measure plate width and length, thus informing the operators when cross-rolling has achieved the desired width and enabling them to control the width thereafter. Loadmeters are valuable for setting the mill parallel, for repeating programmes, and to ensure well planned scheduling to make full use of the mill's load capacity.

CONCLUSIONS

Layout
The modern plate mill should comprise a single 4-high mill, 2-high rougher, and 4-high finisher, or two 4-high mills or a semi-continuous mill (one rougher and four or more 4-high finishers), depending on output and order book make-up.

Heating
The mill should be fed by continuous reheat furnaces with possibly one or two in-and-out furnaces to deal with the awkward 10% of orders.

Mill type
The finishing mill should always be 4-high. Adequate main drive power must be installed to make sure full advantage is taken of heavy reductions.

Descaling
Great attention must be paid to the proper location of high-pressure water sprays at all descaling stations to ensure a clean plate throughout the operation.

Finishing equipment
This must be laid out generously for modern high outputs. Rocking blade shears should be used instead of normal guillotines, and rotary side trimmers for all plate $\frac{3}{4}$ in. thick and below. Normalizing facilities and cold levelling equipment should be installed.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance given them during discussion at the following plate mill plants: Appleby Frodingham Steel Co., South Durham Steel and Iron Co. Ltd, Consett Iron Co. Ltd, Colvilles Ltd, Koninklijke Nederlandsche Hoogovens en Staalfabrieken NV, SA Cockerill-Ougrée, Ruhrstahl Henrichshütte, Hattingen, Dillingen Hüttenwerke, AG. They also acknowledge the assistance of Mr W. Barr, O.B.E., of Colvilles Ltd, and of their colleagues, particularly Mr J. Smith, metallurgical specialist engineer, and Mr P. A. Clark, assistant chief engineer, both of Davy and United Engineering Co. Ltd. They also thank Davy and United Engineering Co. Ltd for permission to publish the paper.

Table II is taken from the paper by A. P. Baines and H. S. Brown: 'Developments in electrical equipment for reversing plate mills', Nema Standards 1959, Pt.13, and is reproduced by kind courtesy of English Electric Co. Ltd, Stafford.

NEWS

Announcements and News of Science and Industry

THE IRON AND STEEL INSTITUTE

Medals and Prizes

The Council of the Institute has announced the award of the following medals and prizes:

Bessemer Gold Medal for 1960

To Professor Dr HERMANN SCHENCK, Director of the Institut für Eisenhüttenkunde, Rheinisch-Westfälische Technische Hochschule Aachen, Germany, and President of the Verein deutscher Eisenhüttenleute.

Sir Robert Hadfield Medal for 1960

To Dr J. C. HUDSON, Head of the Corrosion Section, Chemistry Department, British Iron and Steel Research Association.

Andrew Carnegie Silver Medal for 1959

To Dr P. R. V. EVANS, Armour Research Foundation, Chicago, for a paper on *The effect of rolling unstable austenitic 0·76% carbon steel at 220–300°C* (*Journal*, 1959, Jan., vol.191, pp.34–44); his co-author, Professor Hugh O'Neill, was not eligible for an award.

Williams Prize for 1959 (£100)

To Mr I. M D. HALLIDAY, Head of Continuous Casting Research, The United Steel Companies Ltd, Research and Development Department, Rotherham, for his paper *Continuous casting at Barrow* (*Journal*,1959, Feb., vol.191, pp.121–163).

Ablett Prize for 1959 (£100 each)

To Mr V. HARRISON and Mr V. STEPHENSON, both of Dorman Long (Steel) Ltd, for their paper *The new medium-section mill at the Cleveland works of Dorman Long (Steel) Ltd* (*Journal*, 1959, June, vol.192, pp.132–142).

Additional Honorary Members of Council

At a recent meeting of the Council of the Institute, the following Additional Honorary Members of Council were elected, to serve for three years:

Dr J. NUTTING, Lecturer in Metallurgy in the University of Cambridge and Professor-Designate of Metallurgy in the University of Leeds.

Dr W. S. WALKER, Director of Round Oak Steel Works Ltd.

Annual General Meeting 1960

The Ninety-First Annual General Meeting of the Institute is being held in London from **3 to 5 May 1960.** The main technical sessions will be devoted to a symposium on the production of wide strip, at which papers from Italy, the Netherlands, the UK, and the USA are to be presented and discussed. There will also be a session devoted to electric-arc steelmaking.

The formal business and induction of the new President, together with the delivery of the Presidential Address, will take place at the Royal Commonwealth Society, Northumberland Avenue, London WC1, on the morning of Tuesday, 3 May, and this will be followed in the afternoon by the first session of the symposium on wide strip. The subsequent sessions in the symposium will take place at the Great Hall, Caxton Hall, Caxton Street, London SW1, on Wednesday and Thursday, 4 and 5 May. The session on electric steelmaking will be held at Convocation Hall, Church House, Great Smith Street, London SW1, on the morning of Thursday, 5 May.

Full details of the programme of the meeting will be found on p.249 of the February issue of the *Journal*.

The Dinner for Members is being held at Grosvenor House, Park Lane, London W1, on the evening of Wednesday, **4 May.** The Rt Hon. Richard Wood, P.C., M.P., Minister of Power, will propose the toast of *The Iron and Steel Institute and industry*.

Determination of gases in metals

A symposium on *The determination of gases in metals*, organized by the Society for Analytical Chemistry in conjunction with The Iron and Steel Institute and The Institute of Metals, is being held at Denison House, 296 Vauxhall Bridge Road, London SW1, on Tuesday and Wednesday, **3 and 4 May 1960.** The meeting is open to members of the three societies and their guests. The full programme of the meeting appeared on p.249 of the February issue of the *Journal*.

Award for President-Elect

It has been announced by the Associazione Italiana di Metallurgia that they are to award their Federico Giolitti Steel Medal, one of the Association's highest honours, to Mr W. F. Cartwright, President-Elect of The Iron and Steel Institute. The medal will be presented to Mr Cartwright at the Joint Meeting of the Associazione Italiana di Metallurgia and The Iron and Steel Institute in Milan on 30 May 1960.

Special Meeting in Italy

The Council of the Institute have accepted an invitation from the Associazione Italiana di Metallurgia to hold a Joint Meeting with them in Milan on Monday and Tuesday, **30 and 31 May 1960.** This Joint Meeting will form part of the Special Meeting of the Institute, to be held in Italy from Sunday, **29 May,** to Saturday, **11 June 1960.**

The meeting will be divided into three sections: the first, from 29 May to 3 June, in Milan and Genoa; the second, from 4 June to 7 June, in Rome; and the third, from 8 June to 11 June, in Naples. In addition to the Joint Meeting with the AIM, there will be visits to works in the three areas, social functions, and sightseeing excursions. An outline of the programme appeared in the March issue of the *Journal*, p.385, and the full programme is being published in the May issue, together with a survey of the Italian iron and steel industry.

NEWS OF MEMBERS

Mr **A. D. Baynes** has joined Samuel Osborn and Co. Ltd.

Mr **D. Bird** has been appointed general manager of the Corby iron and steelworks of Stewarts and Lloyds Ltd.

Major **W. R. Brown,** D.S.O., has retired from the board of the Power–Gas Corporation Ltd and from the chairmanship of the company.

Mr **D. F. Campbell** has been appointed president of the Metallurgical Equipment Export Co. Ltd.

Mr **W. J. Campbell** is now works manager (blackheart division) with William Lee and Sons Ltd, Dronfield.

Mr **J. G. Colvin** has been appointed personal assistant to the managing director, iron and steelworks, of Stewarts and Lloyds Ltd.

Dr **C. J. Dadswell** is now chairman of Davis and Lloyd (1955) Ltd.

Capt. **H. Leighton Davies** is to succeed Lord Monckton as chairman of the Industrial Welfare Society.

Dr **D. W. Davison** has been transferred to the central personnel executive staff of the Plessey Co. Ltd, to assist the personnel director with scientific and technical appointments throughout the company.

Mr **W. H. Everard** has joined the board of Park View Steel Works Ltd.

Mr **J. Glen** has been appointed general manager, iron and steel development (metallurgical) at Stewarts and Lloyds Ltd.

Dr **Ray W. Guard** has transferred to the metallurgical products of the General Electric Company, Detroit.

Mr **C. P. Gunstone** is now an assistant general manager of the Corby iron and steelworks of Stewarts and Lloyds Ltd.

Mr **H. S. Gupta** has joined the Indian Smelting and Refining Co. Ltd, Bombay, as chief works metallurgist.

Mr **A. L. Hodge** is now associate manager, development, gas processes (metallurgy) in the development laboratory of the Linde division of the Union Carbide Corporation.

Dr **J. H. Hollomon** has been appointed general manager of the general engineering laboratory of the General Electric Company, Schenectady.

Dr **Samuel L. Hoyt** has been appointed staff representative in Europe of the VS Department of Defence's Research and Engineering Department.

Mr **K. R. Jason** has been elected a Fellow of The Institution of Metallurgists.

Mr **R. F. Jennings** has been made a director of Huntington, Heberlein and Co. Ltd.

Mr **A. M. Lee** has joined the board of John Shaw Ltd.

Mr **G. Wilton Lee** has joined the board of John Shaw Ltd.

Mr **H. F. Padbury** has been appointed assistant works manager (coke, iron, and steel) at the new Spencer Works of Richard Thomas and Baldwins Ltd.

Mr **R. H. Parker** has been appointed works manager of the new Spencer Works of Richard Thomas and Baldwins Ltd.

Mr **G. A. Pickup** has left the UKAEA to become a lecturer in metallurgy at Manchester College of Technology.

Mr **G. B. Sankey** is now assistant managing director of Joseph Sankey Ltd.

Sir **Frederick Scopes** has joined the board of Chamberlain and Hill and has been elected chairman.

Mr **T. J. J. Smith** has been appointed senior lecturer in metallurgy at the Sheffield College of Technology.

Mr **A. Stirling** is now general manager, central iron and steel works office, of Stewarts and Lloyds Ltd.

Professor **Albert de Sy** has been nominated a Member of the Academy of Science (Royal Flemish Academy of Belgium) and elected an honorary member of the Société Française de Métallurgie.

Mr **R. N. M. Ward** has joined the London staff of Guest Keen Iron and Steel Co. Ltd.

Dr **C. D. Weir** is now reader in mechanical engineering at the University of Hong Kong.

Mr **W. B. Wragge** has been appointed managing director of Exors. of James Mills Ltd and Bredbury Mills Ltd.

Obituary

Monsieur **Roger L. Dardenne** (*elected* 1946), of Paris.

Mr **John Haker** (*elected* 1948), of Johannesburg, South Africa, on 3 February 1960.

Dr **Francis Anthony Ernest Musson** (*elected* 1958), of Westcliff-on-Sea, in June 1959.

Mr **Samuel Baron Turner** (*elected* 1953), of Sheffield, on 15 February 1960.

Mr **George Wood,** C.B.E. (*elected* 1928), of Sheffield, on 14 March 1960.

EDUCATION

Refresher courses at Battersea

The Department of Metallurgy, Battersea College of Technology, London SW11, has organized a number of refresher courses for older graduates, to be given at the College during the Easter and summer vacations in the current session. The courses will last three or four days, and will be given by members of the College staff and visiting lecturers.

The first courses planned will be as follows:
The structure of metals and alloys, April 1960
Developments in foundry practice, July 1960
Austenite transformation: the present position September 1960

The courses are intended for metallurgists who, having completed their academic studies some years ago, may now like to survey the present state of knowledge in fields additional to their own speciality.

New FBI handbook

The Federation of British Industries has issued a handbook entitled 'The Technical colleges and their government'. It contains recommendations on governing bodies, and considers the structure of technical education in England and Scotland against its historical background. Other chapters deal with the academic pattern, the finance of technical education, and the government of technical colleges. Further education is considered in appendixes and a selected bibliography is given.

NIFES Oil-firing courses

Three-day courses on oil firing are arranged at frequent intervals by the National Industrial Fuel Efficiency Service. The next one will be held from 3 to 5 May 1960, at Ailsa House, Kings Road, Reading.

The course has been designed to meet the needs of industrial plant engineers, heating engineers, and supervisory staff responsible for oil-fired boiler plants.

The fee for the course, exclusive of hotel accommodation, will be 6 guineas. Application forms, and a course syllabus may be obtained from the National Industrial Fuel Efficiency Service, 71 Grosvenor Street, London W1.

Summer school in health physics

A summer school in health physics (radiation protection) arranged by Dr H. D. Evans, lecturer in radiation hazards and health physicist, will be held for two weeks from 4 July in the Nuclear Technology Laboratories forming part of the Department of Chemical Engineering and Chemical Technology, Imperial College, London. The fee for the course is 25 guineas exclusive of residence, although residential facilities will be available in College hostels. Applications for admission should be made to the Registrar, Imperial College, South Kensington, London SW7, from whom further information may be obtained.

Graduate course in foundry science and engineering

The University of Birmingham announces a graduate course under this title. The broad aim of the course is to provide advanced university training in the combined fields of foundry science and engineering. The course assumes prior training in metallurgy, science, or engineering up to degree standard.

Forms of application may be obtained from the Registrar, The University, Edgbaston, Birmingham 15, and further information about the course from the Secretary of the Department of Industrial Metallurgy at the same address.

FORTHCOMING CONFERENCES AND EXHIBITIONS

Colloquium on sheet metal

A colloquium on the shaping of sheet metal and the testing of sheet has been organized jointly by the International Deep Drawing Research Group and the Société Française de Métallurgie. The colloquium will be held in Paris from 23 to 25 May. Thirty papers will be presented on various topics including anistropy, cup-forming tests, and new techniques. Full details are available from the Secrétariat de la Société Française de Métallurgie, 25 rue de Clichy Paris 9ème.

Australian Institute of Metals conference

The 13th Annual Conference of the Australian Institute of Metals is to be held at Port Kembla from 23 to 30 May. The theme of the conference is 'Flat rolled products', and those attending will have the opportunity to see each stage in the manufacture of plate, sheet, and tinplate on equipment recently installed at Port Kembla. Further particulars are obtainable from The Conference Secretary, Australian Institute of Metals, P.O. Box 14, Port Kembla, New South Wales.

Open days at NEL

The National Engineering Laboratory is holding open days on Wednesday and Thursday, 15 and 16 June. The laboratory will be open for inspection and there will be special displays of items developed since the last open days. Applications for invitations, stating which day is preferred, should be sent to The Director, National Engineering Laboratory, East Kilbride, Glasgow.

Foundrymen's conference at Malvern

The annual conference of The Institute of British Foundrymen is being held at Malvern from 21 to 24 June. A full programme of technical sessions, works visits, and entertainments has been arranged. Full information is available from The Institute of British Foundrymen, 14 Pall Mall, London SW1.

Protection of gas plant and equipment from corrosion

A joint symposium on this topic has been arranged by the Institution of Gas Engineers and the Corrosion Group of the Society of Chemical Industry, to be held at the College of Advanced Technology, Gosta Green, Birmingham 4, on 22 and 23 September. Attendance is open to all. The registration fee is 2 guineas to members of the sponsoring bodies and to *bona fide* students of universities and technical colleges, and 3 guineas to others. Further information may be obtained from A. S. Blower, College of Advanced Technology, Department of Chemistry, Suffolk Street, Birmingham 1.

Société Francaise de Métallurgie

The theme of this year's Journées Métallurgiques d'Automne, to be held at the Maison de la Chimie, 28bis rue Saint-Dominique, Paris 7e, from 17 to 21 October, will be *Heat-treatment of metals and alloys*. The subjects will be considered under the following headings: physicochemical aspects of changes brought about by heat-treatment, problems of treating objects in different steels, the application of heat-treatment to new ferrous and non-ferrous alloys, and the heat-treatment of large castings and forgings. Those wishing to submit papers should inform the Secretary of the Société at 25 rue de Clichy, Paris 9e, before 1 April; the title and a summary of 500–1000 words should be sent by 1 July.

Institute of Welding Autumn Meeting

The Institute of Welding has announced that its Autumn meeting will be held in London, 1–3 November. The meeting will be devoted to the general theme of the metallurgy of welding and brazing. Papers already promised include 'The effect of austenitizing time and temperature on formation of martensite', 'A critical appraisal of cracking tests', 'The use of welding in chemical plants in the UKAEA', 'The quality of weld deposits made by different welding processes', 'The influence of grain size on the properties for mild-steel welds', 'An investigation into the origin of cracking in welded stainless steel using an autoradiographic technique', and 'The high-frequency induction brazing of dissimilar metals'.

Members of The Iron and Steel Institute are invited to attend the discussion meetings at which these papers will be presented.

International congress on metallic corrosion

The First International Congress on Metallic Corrosion to be held under the auspices of the International Union of Pure and Applied Chemistry will take place in London on the 10–15 April 1961. A Scientific Committee has been set up, under the Chairmanship of Mr L. Kenworthy (the present Chairman of the Corrosion Group of the Society of Chemical Industry), to organize scientific sessions of the Congress, and the Committee now invites papers on any aspect of metallic corrosion for presentation at the Congress meetings. It is intended to devote much of the Congress to discussion of papers dealing with original work, but first class up-to-date review papers will also be welcome.

Preprints will be issued well before the Congress and authors of papers accepted will be invited to introduce their papers briefly for discussion at the meetings. All papers, together with discussions, will subsequently be published in book form as the Proceedings of the 1st International Congress on Metallic Corrosion: London 1961, and papers accepted for presentation at the Congress must not be published elsewhere without permission of the publishers.

Those wishing to submit papers, which should preferably be in English, should send the title and a synopsis before 30 April 1960. The complete manuscript in duplicate of all accepted papers must reach the organizers *not later than 31 August 1960*. The Scientific Committee reserves the right to limit the number of papers presented in order to ensure adequate time for discussion.

Papers, synopses, and correspondence regarding papers should be sent to the Hon. Secretary of the Scientific Committee, Mr H. S. Campbell, The British Non-Ferrous Metals Research Association, Euston Street, London NW1. All other enquiries should be addressed to The Hon. Secretary, 1st International Congress on Metallic Corrosion: London, 1961, 14 Belgrave Square, London SW1.

NEWS OF SCIENCE AND INDUSTRY

Changes on Iron and Steel Board

Sir Thomas Williamson and Mr Harry Douglass have been appointed part-time members with effect from 1 June, in place of Sir Andrew Naesmith and Mr J. Owen, whose appointments expire on 31 May.

New division formed at S. and L.

An important development involving the creation of a new division was announced recently by Stewarts and Lloyds Ltd. This is the formation of a Pipework Engineering Division to be responsible for making and marketing all forms of manipulated pipework. The division will be under separate management with its own sales, engineering, and manufacturing departments, and has been set up to co-ordinate the manufacturing resources, technical experience, and practical and scientific knowledge of the company in this connexion, and to deploy them to the best advantage.

Skefko golden jubilee

The Skefko Ball Bearing Co. Ltd of Luton celebrated its golden jubilee on 7 February, marking the occasion with a special issue of its house journal, the *Inner Ring*.

Highlights of each year since the company's foundation in the UK are recalled in text and illustration, including some rare and curious photographs. The company's recent rapid expansion, with increases in production, sales, and employment is seen as a promising start to the second 50 years of its history.

Tin research in 1959

The Annual Report of the Tin Research Institute describes several new lines of investigation in metallurgy, tinplate, electrodeposition, and in 'organotin' chemistry.

In the metallurgical field, systematic investigations are continuing into the alloys of tin with the newer metals titanium, zirconium, and niobium. The effects of tin in cast iron and in steels are being further studied and practical trials are being made with cast irons containing prescribed additions of tin. Bright deposits of tin can be made by electrodeposition using wood tar additions in the plating vat. The Institute is trying to discover which constituents of the tars are effective so that the process can be simplified.

Several new studies of the properties of tinplate are mentioned. A new method of assessing porosity of tin coatings by measurement of flow of current is described. Organotin researches are pointing the way to new types of compounds of greater complexity which are likely to have industrial uses.

The report gives a long account of the activities of the Institute and its eight branches in other countries. Over 2000 requests for technical help were received during the year. The Institute continued to organize lectures, conferences, and exhibitions and distributed its publications and quarterly journal '*Tin and its uses*' to all countries, free of charge.

Copies of the report are available to libraries and to organizations interested in tin and its applications, from Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex.

Coil spring laboratories opened

On 24 March Sir Harry Melville of DSIR opened the new research Laboratories of the Coil Spring Federation Research Organization at Sheffield. He spoke of the need for more research and application of the results of such research, particularly in a comparatively small and specialized industry obliged to meet competition from alternative products, such as the recent introduction of rubber as a spring material for motor cars.

Sir Harry urged the industry to use its laboratories to establish its exact requirements in raw materials and to insist on these being met by steelmakers.

New analysis equipment for Mond Nickel

A solids mass spectrometer, the first commercially produced machine of its kind in the world, has recently been installed at the Birmingham Laboratories of the Mond Nickel Company. This equipment, supplied by Metropolitan-Vickers, analyses for all elements in the Periodic Table down to one part in 100 million. The laboratory already has one of the first models of a new automatic X-ray fluorescence spectrometer, manufactured by Solartron, which carries out non-destructively precise measurement of the constituents of an alloy exceeding 0·1%.

Safety guide on isotopes

The British Safety Council has published a specially prepared guide to the safe use of isotopes. The subjects covered include the latest uses of isotopes in industry, the protection of workers from radiation hazards, safe working regulations, monitoring, how to set up a radiation protective service, but the booklet is primarily designed to present safety regulations in a readable form.

Copies of the book can be obtained from The British Safety Council, Safety House, 60 Westbourne Grove, London W2.

Indian symposium on pilot plants

A symposium on 'Pilot plants in metallurgical research and development' was held under the auspices of the National Metallurgical Laboratory at Jamshedpur, India, on 15–18 February. The aim of the organizers was to focus attention on the role of pilot plants in metallurgical research and development with a view to exchanging technical knowledge with leading scientists and metallurgists from different parts of the world.

Twenty-seven technical papers were presented and discussed, and during the symposium a new pilot-plant bay was opened by Professor M. S. Thacker, Director-General of Scientific and Industrial Research.

Proceedings of the symposium and abstracts of the papers presented have been published by the National Metallurgical Laboratory, Jamshedpur-7, India.

Latin-American institute

As a result of a meeting held in Santiago, Chile, under the auspices of the Chilean Steel Institute, in September and October 1959, attended by Mr H. W. A. Waring, C.M.G., representing The Iron and Steel Institute and the British Iron and Steel Federation, a Latin-American Iron and Steel Institute has been formed. For the present the new institute will be operated from Santiago, with Sr Fernando Aguirre, managing director of the Chilean Steel Institute, as its secretary-general.

The objects of the new institute are the study of investments in the Latin-American industries, the promotion of standardization of products, the interchange of information and technical experience, the collection of statistics, the promotion of close relations between its members, and collaboration with the object of increasing productivity and the training of technical personnel.

Contract news

The *General Electric Co. Ltd*, in association with Vacuum Industrial Applications Ltd, is to supply a 56-lb vacuum melting furnace to the Sheffield laboratories of BISRA.

A contract for a high-duty universal beam mill has been awarded to *Schloemann AG* of Düsseldorf by the Appleby-Frodingham Steel Company. The new mill will be capable of rolling beams with parallel flanges having webs of 8–24 in. It will consist of a universal mill stand, edging stand, roller tables, and saw line. It is due to go into operation in the summer of 1961.

The new steelmaking plant to be installed by Consett Iron Co. Ltd as part of their current development plan will be the first in the world to use both the LD and the Kaldo oxygen steelmaking processes. The equipment, which will consist of two 100-ton LD converters and one 100-ton Kaldo converter, will be supplied by *Head Wrightson Iron and Steelworks Engineering Ltd*. It is expected to go into production at the end of 1961, and is designed to produce an additional output of about 750,000 tons annually. Head Wrightson are associated with Pintsch Bamag AG, Cologne, and Research Cottrell Inc, USA, in the development of oxygen steelmaking plants.

The order for building the 68-in. wide strip mill at the new Spencer works of Richard Thomas and Baldwins Ltd at Newport, Mon., has been placed with *Davy and United Engineering Co. Ltd*, who are supplying a similar mill for the Ravenscraig works of Colvilles Ltd. The new mill will go into production in October 1961, and will have an initial output of about 1 000 000 tons per year; it is being designed, however, for an eventual output three times as large.

The first two electric-arc furnaces for the new melting shop at Steel, Peech and Tozer are to be supplied by *GWB Furnaces Ltd*. The furnaces, which will be of Demag design, will be of entirely British manufacture. Their internal diameters of 24 ft will give a nominal capacity of 150 tons and will be capable of melting at a rate of 1 ton/min; in practice they will be used for a maximum of 110 tons ingot weight.

INDUSTRIAL PUBLICATIONS RECEIVED

A finely produced 56-page book gives a pictorial survey of the achievements of William Press and Son Ltd and Associates, civil and mechanical engineering contractors.

'Pressure vessels' is the title of leaflet no.544 from the Hadfields group of companies.

Kingscliffe Super-Refractories Ltd survey some of their products in two recent brochures.

An issue of *Machine Tools* from A. A. Jones and Shipman is devoted to the company's Continental customers.

Leaflet no.601 from The Visco Engineering Co. Ltd describes the 'Visco-Handte' wet-type dust collector, while a new oil-wetted filter, the 'K.M.' type, is described in leaflet 598.

Motors for cranes, hoists, and lifts are detailed briefly in a leaflet from the Lancashire Dynamo and Crypto Ltd.

Some features of air-cooled heat exchangers are set out in publication 258 of the heat exchange division of Wellington Tube Works Ltd.

Publication no.13 from Rocol Ltd describes the company's molybdenized lubricants.

'Modern gas producer plant' is a new brochure from the International Furnace Equipment Co. Ltd.

Solus-Schall Ltd devote no.16 of *SS News Letter* to non-destructive testing.

'Retroflex' bag filters are described in a folder no.82 issued by W. C. Holmes and Co. Ltd.

The Morgan Crucible Co. Ltd have issued two new technical leaflets: ZD.37, 'Current collection', and RD.83 'Refractories for land boilers'.

DIARY

4 Apr. CLEVELAND INSTITUTION OF ENGINEERS—*A modern plate mill*, by M. F. Dowding—Cleveland Scientific and Technical Institution, Middlesbrough, 6.30 pm.

4–5 Apr. CORROSION SCIENCE SOCIETY—First Meeting—Battersea College of Technology, London SW11.

6–7 Apr. THE IRON AND STEEL INSTITUTE (Engineers Group)—Melting on plate mills—4 Grosvenor Gardens, London SW1.

6 Apr. SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—*The presentation of corrosion information*, by Dr J. W. Jenkin—14 Belgrave Square, London SW1, 6 pm.

7 Apr. LEEDS METALLURGICAL SOCIETY—*Metallurgical research in the DSIR*, by Dr N. P. Allen, F.R.S.—6.30 pm.

7 Apr. LIVERPOOL METALLURGICAL SOCIETY—*The examination of irradiated fuel elements*, by Dr G. B. Greenough, and 12th Annual General Meeting—Department of Metallurgy, Liverpool University, 7 pm.

8 Apr. WEST OF SCOTLAND IRON AND STEEL INSTITUTE—Annual General Meeting—39 Elmbank Crescent, Glasgow, 6.45 pm.

12 Apr. POWDER METALLURGY JOINT GROUP—Symposium on *Continuous processing in powder metallurgy*, Hoare Memorial Hall, Church House, London SW1, 10.30 am.

21 Apr. SOCIETY OF CHEMICAL INDUSTRY (Corrosion Group)—Annual General Meeting and *Electrode processes in primary batteries*, by D. H. Collins—14 Belgrave Square, London SW1, 6 pm.

22 Apr. LINCOLNSHIRE IRON AND STEEL INSTITUTE–27th Annual Dinner—Scunthorpe.

25 Apr. SHEFFIELD SOCIETY OF ENGINEERS AND METALLURGISTS—Film night—Engineering Lecture Theatre, St George's Square, Sheffield, 7.30 pm.

25–29 Apr. 1ST INTERNATIONAL COMPRESSED AIR AND HYDRAULICS EXHIBITION—Empire Hall, Olympia, London.

2–4 May INSTITUTE OF PHYSICS and SOCIÉTÉ FRANÇAISE DE MÉTALLURGIE—Meeting on non-destructive testing—47 Belgrave Square, London SW1.

3–4 May SOCIETY FOR ANALYTICAL CHEMISTRY, THE IRON AND STEEL INSTITUTE, and THE INSTITUTE OF

	METALS—Symposium on *The determination of gases in metals*—Denison House, London SW1.
3–5 May	THE IRON AND STEEL INSTITUTE—Annual General Meeting (*see* p.495 for details).
5–13 May	MECHANICAL HANDLING EXHIBITION—Earl's Court, London.
7 May	SWANSEA AND DISTRICT METALLURGICAL SOCIETY—Annual General Meeting—Central Library, Swansea, 7 pm.
9–11 May	INSTITUTE OF WELDING—Spring Meeting—Droitwich.
12 May	LEEDS METALLURGICAL SOCIETY—Visit to Cotton and Co. Ltd.

BRITISH IRON AND STEEL INDUSTRY TRANSLATION SERVICE

The following translations are now available, in addition to those given on page 388 of the March 1960 issue of the *Journal*:

Problems related to the home production of fluxes and wires for submerged arc welding and surfacing. (Abridged from *Przeglad Spawalnictwa*, 1955, (1), pp.7–12.)
WĘGRZYN, J., *Przeglad Spawalnictwa*, 1957, March, pp.82–84. (£4 10*s*. 0*d*.) [1337

Surface hardening of gears.
HÖHNE, E., *VDIZ*, 1958, Feb. 21, pp.241–248. (£7) [1343

Improvements in the quality of steel CSN 12 040 for cold formed screws.
TLUSTA, D., from 'Vyzkumńe Práce z Oboru Železa a Oceli'. Prague, Ministerstvo Hutniho Prûmyslu a Rudnych Dolu, 1958, pp.173–188. (£6 15*s*. 0*d*.) [1345

Basic problems in the theory of piercing.
DANILOV, F. A. *et al*., from 'Production of Steel Tubes by Hot Rolling'. Moscow, *Metallurgizdat*, 1954, Chap.6, pp.58–93. (£9) [1354

Rapid method for determining the basicity of open-hearth slags.
ENDE, H. VOM., and BARDENHEUER, F., *Arch. Eisenhütt*., 1959, July, pp.391–396. (£5) [1423

Calculation of the reheating process of steel ingots and comparison with the results as measured.
WARTMANN, R., *Stahl u. Eisen*., 1959, May 14, pp.703–711. (£5 5*s*. 0*d*.) [1439

Equilibria of carbon and oxygen in liquid iron and the effect of low silicon contents upon the equilibria.
SCHENCK, H., and GERDOM, K. H., *Arch. Eisenhütt*., 1959, Aug., pp.451–460. (£5 15*s*. 0*d*.) [1461

A study of the precipitation of Fe_2O_3 in the scale produced on iron at high temperatures.
PAIDASSI, J., *Rev. Mét*., 1955, (11), pp.869–886. (£7 5*s*. 0*d*.) [1469

The hydraulic 25-ton bar drawing bench of the Max-Planck-Institut für Eisenforschung and its possibilities.
LUEG, W., and PAWELSKI, O., *Stahl u. Eisen*., 1958, Dec. 11, pp.1812–1815. (£4) [1476

An analysis by statistical methods of the metallurgical processes involved in the production of tube steels.
KNOTEK, M., *Hutnické Listy* (Prague), 1958, (3), pp.287–298. (£8 15*s*. 0*d*.) [1482

Results obtained from running two gas turbine plants in Belgian metallurgical works.
AGUET, E., *Stahl u. Eisen*., 1959, Oct. 15, pp.1479–1483. (£4) [1494

The velocity of sound as a characteristic value for the quality of cast iron. (From German.)
ZIEGLER, R., and GERSTNER, R., 24th International Foundry Congress, 1957, (6), pp.133–157. (£4 15*s*. 0*d*.) [1496

The influence of the degree of eccentricity in a Stiefel piercing mill on the possible formation of external spiral defects during piercing.
DEDEK, V., *Hutnické Listy* (Prague), 1958, (10), pp.882–892. (£8 10*s*. 0*d*.) [1506

The effect of cold deformation on the structure of austenitic grains (an electron microscope study).
HRIVNAK, I., *Hutnické Listy* (Prague), 1959, (6), pp.507–511. (£5 10*s*. 0*d*.) [1509

The problem of the distribution of precipitates in corrosion-resistant austenitic steels.
ČIHAL, V., and JEZEK, J., *Hutnické Listy* (Prague), 1959, (8), pp.695–700. (£5 5*s*. 0*d*.) [1511

Stresses at the joint face of austenite-ferrite welds.
SCHILLER, A., *VGB Mitt*., 1958, June, pp.176–180. (£2 15*s*. 0*d*.) [1513

The use of austenitic steels in the new power station at Hüls.
ENGL, A., *VGB Mitt*., 1958, Aug., pp.255–264. (£4 10*s*. 0*d*.) [1514

Summary of the results of joint long-time creep tests: Conclusions for steam-plant construction.
RUTTMANN, W., and SCHINN, R., *VGB Mitt*., 1958, Dec., pp.411–420. (£4 15*s*. 0*d*.) [1515

The reactions occurring in the blast-furnace as seen from the kinetic point of view.
HEYNERT, G., and WILLEMS, J., *Stahl u. Eisen*., 1959, Oct. 29, pp.1545–1554. (£5 10*s*.0d.) [1518

Properties of steel for cold pressing of bolts.
HAJEK, S., *Hutník* (Prague), 1957, (4), pp.116–122. (£5 10*s*. 0*d*.) [1524

Simulating and controlling computers for arc steelmaking furnaces.
EFROIMOVICH, Yu. E., *Stal'*, 1957, July, pp.602–608. (£6 5*s*. 0*d*.) [1528

The secondary hardness of high-speed steel.
JEZEK, J., and VOBORIL, J., *Hutnické Listy* (Prague), 1959, (1), pp.47–54. (£6 5*s*. 0*d*.) [1530

Melting in electric furnaces.
HÁJEK, M., *Slévárenství* (Prague), 1958, (12), pp.384–390. (£5 10*s*. 0*d*.) [1532

Contribution to the problem of the production of N 80 normalized oil tubes from manganese steel.
ŠEJNOHA, R., and PROCHÁZKA, L., *Hutnické Listy* (Prague), 1959, (7), pp.569–573. (£5) [1539

Research on the rolling process (incl. bibl., 252 refs).
PAVLOV, I. M., from 'Metallurgiya SSSR 1917–1957', ed. I. P. Bardin, Moscow, *Metallurgizdat*, 1959; vol.2, pp.56–81. (£8) [1542

The displacement of the non-variance point between iron, wüstite, magnetite, and oxygen in the system iron–oxygen by alloying elements or foreign oxides. Effects on the behaviour of iron alloys in scaling.
BRAUNS, E. *et al*., *Arch. Eisenhütt*., 1959, Sept., pp.553–564. (£8 15*s*. 0*d*.) [1551

Ring rolling and the construction of ring mills (with discussion).
WEBER, K.-H., *Stahl u. Eisen*., 1959, Dec. 24, pp.1912–1923. (£7 15*s*. 0*d*.) [1555

Nitrogen absorption during electric arc welding.
BISCHOF, F., *Technik*, 1949, May, pp.229–234. (£4 10*s*. 0*d*.) [1556

Factors influencing the behaviour of some types of austenitic and ferritic steel during hot deformation. (From Polish).
TERLECKI, E., *Hutnik* (Poland), 1957 vol.24 June, pp.222–227. (£5 5*s*. 0*d*.) [1557

Sintered alumina cutting tools. I. Theory.
GION, L., *Silicates Industriels* (Brussels), 1958, May, pp.241–247. (£4 10*s*. 0*d*.) [1558

Sintered alumina cutting tools. II. Fabrication factors (with discussion).
GION, L., *Silicates Industriels* (Brussels), 1958, June, pp.327–332. (£7 10*s*. 0*d*.) [1559

Influence of ageing on the precipitation phenomena occurring in temper-rolled sheets made of deep-drawing steel.
FUNKE, P. jun., and LUEG, W., *Stahl u. Eisen*., 1959, Oct., pp.1398–1411. (£8 15*s*. 0*d*.) [1561

Influence of various trace elements on the forgeability of steel.
ROSSARD, C., and BLAIN, P., *Rev. Mét*., 1959, Aug.–Sept., pp.175–180. (£3) [1565

Magnetic particle inspection and the most recent methods of indication.
MARSCHALL, H. J., *Werkstatt u. Betrieb*, 1958, Nov., pp.649–653. (£4 10*s*. 0*d*.) [1567

A solution microtechnique for the spectrochemical analysis of oxide inclusions in steels.
MEYER, S., and KOCH, O. G., *Spectrochimica Acta*, 1959, (8), pp.549–556. (£2 5*s*. 0*d*.) [1569

On the origin of coloured spot on tinplate.
SANDLER, N. I., and SOLOV'EVA, G. G., *Stal'*, Metallography and heat-treatment suppl., 1958, pp.247–250. (£1 10*s*. 0*d*.) [1570

Influence of the surface boundary layer on the frictional behaviour of austenitic materials in cold-forming in the deep-drawing process.
WIEGAND, H., and KLOOS, K. H., *Metalloberflache*, 1959, Aug., pp.229–233. (£2 10*s*. 0*d*.) [1573

Production of steel from high phosphorus pig iron by top blowing of oxygen with lime powder.
METZ, P. *et al*., *Stahl u. Eisen*., 1960, Jan. 7, pp.20–27. (£5 10*s*. 0*d*.) [1576

The colorimetric estimation of traces of the sulphate ion.
IWASAKI, I. *et al*., *J. Chem. Soc. Japan, Pure Chemistry Section*, 1953, vol.74, pp.400–401. (£2) [1577

The performance of the grid of a hammer mill.
BEREZIN, B. V., *Koks i Khim*., 1957, (5), pp.51–55. (£3 5*s*. 0*d*.) [1580

The grinding of coal for the production of coke. II. Disintegrating and impact hammer type mills.
CHARVAT, V., *Paliva*, 1956, (6), pp.185–192. (£6 15*s*. 0*d*.) [1581

The pressure and supply of wind to the blast-furnace.
THIERRY, P., *Métallurgie* (Paris), 1953, (1), pp.15–19. (£4 5*s*. 0*d*.) [1582

Energy problems of blast-furnace operation at elevated pressures.
KUNAKOV, N. E., *Stal'*, 1955, July, pp.637–639. (£4 5*s*. 0*d*.) [1583

Non-destructive materials testing, magnetic particle inspection. III. Innovations.
MARSCHALL, H. J., *Arch. tech. Messen u. Industrielle Messtechnik*, Lieferung 283, V 91 191–3, 1959, Aug., pp.161–164. (£3 10*s*. 0*d*.) [1590

Influence of thickness of steel sheets between bricks on roof life.
TSYGANKOV, E. M., *Metallurg*., 1959, April, pp.17–19. (£1 15*s*. 0*d*.) [1600

Methods of operation, and practical experiences, in the automatic spectrographic analysis of steel and pig iron.
MÖLLER, P., *Arch. Eisenhütt*., 1959, Oct. (£4 5*s*. 0*d*.) [1604

Metallurgiya SSSR (1917–1957), ed. I. P. Bardin, Moscow, *Metallurgizdat*, 1959. List of contents of vol.II.
AKADEMIYA NAUK SSSR. Vsesoyuznyi institut nauchnoi i tekhnicheskoi informatsii. (No charge.) [1606

Electrochemical polishing of the internal surfaces of tubes.
STÖCKL, E., *Blech*, 1959, Oct. (£2) [1620

Present-day possibilities of low-scale and scale-free heating of steel for hot working.
VEH, P. O., *Industrie-Anzeiger*, 1959, April 7, pp.410–412. (£4) [1625

Precipitation processes in austenitic chromium-nickel steels and their effects on susceptibility to intergranular corrosion (with discussion).
WIESTER, H.-J. *et al*., *Arch Eisenhütt*., 1959, May, pp.299–309. (£10) [1627

Stress field as a fundamental tool in crane design.
KLOTH, W., *Stahl u. Eisen*., 1960, Feb. 4, pp.159–164. (£4 10*s*. 0*d*.) [1628

Wear resistant surface layer welding using a horizontal plate electrode (translated from a German version).
KONTOROV, B. M., and POPOVA, N. V., *Svaroch. Proizv*., 1959, (9), pp.27–30. (£2 5*s*. 0*d*.) [1629

On hot cracking of austenitic chromium–nickel welds.
HIRSCH, W., and FRITZE, H. W., *Schweissen u. Schneiden*, 1956, (3), pp.81–85. (£4) [1633

Organic solvents in flame spectrometry.
PÜSCHEL, A., and ECKHARD, S., *Arch. Eisenhütt*., 1959, Dec., pp.731–735. (£3 10*s*. 0*d*.) [1636

Possibility of co-existence of stress corrosion and pitting corrosion in mild steels.
RÄDEKER, W., *Arch. Eisenhütt*., 1959, Dec., pp.747–750. (£2 10*s*. 0*d*.) [1637

Determination of tantalum in titanium alloys by ultraviolet spectrophotometry.
DOBKINA, D. M., and PETROVA, E. I., *Zavods. Lab*., 1957, (4), pp.421–422. (£2) [1642

The balance sheet of an experimental melt in an oxygen blown converter.
SOROKIN, P. Ya., *Stal'*, 1958, Nov., pp.987–992. (£4 5*s*. 0*d*.) [1649

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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• Abstracts, the reference to which is marked with an asterisk, are or are to be made available as translations.

ABSTRACTS

These abstracts are also available on index cards in advance of publication in the *Journal*, each abstract being classified under the Universal Decimal system (UDC). Details and subscription notes can be obtained from the Secretary, The Iron and Steel Institute.

MINERAL RESOURCES

Iron ores J. Serrano (*Met. y Electr.*, 1959, **23**, Aug., 98–100) A short survey of the principal iron mines in the provinces of Biscay, Leon, Teruel, and Granada, which together produce 65% of the total Spanish ore output, with characteristics of ores and tonnages of several leading mines.—S.H.-S.

Sampling East Texas iron ores W. F. Brown (*US Bur. Mines Rep. Invest.*, 5488, 1059, pp.32) Occurrence, drilling, and sampling of cored sections for dressing and metallurgical tests are described.

Manganese supplies for the French iron and steel industry (*Aciers Fins Spéc.*, July, 11–12) The sources and uses of Mn ores are briefly surveyed.

The Nicaro (Cuba) nickel ores R. B. Fisher and W. M. Dressel (*US Bur. Mines Rep. Invest.*, 5496, 1959, pp.54) A mineralogical study with differential thermal analyses in controlled atmospheres.

ORES—MINING AND TREATMENT

Eliminating iron from mixtures of metal sulphates by thermal decomposition F. N. Pavlov and P. A. Pazdnikov (*Trudy Inst. Metallurgii*, 1958, (2), 227–233) To separate the iron from mixed sulphate solutions obtained by hydrometallurgy from polymetallic concentrates, evaporation of the solutions is recommended with subsequent selective decomposition of the iron sulphates into iron oxides at 600–650°. This may be carried out in the stack of a furnace with atomization of the sulphate solutions. By leaching out with water, the residue of undecomposed sulphates (copper, zinc, cadmium, etc.) dissolves and practically pure iron oxide settles out. From it, by reduction at between 900–1000° cuprous iron powders can be obtained.

Interaction of iron sulphides with sulphurous anhydride N. P. Diev, V. V. Paduchev, and V. V. Toporova (*Trudy Inst. Met.*, 1958, (2), 95–105) The investigation of the interaction of solid iron sulphides with SO_2 and conversely of solid magnetite with sulphur was carried out between 700–1180° by means of a continuous current of SO_2 and the determination of the equilibrium composition of the products, after quenching the corresponding materials in evacuated and welded quartz ampoules. The findings confirm among others that the interaction of iron sulphide with SO_2 cannot be determined by the reversible reaction $3FeS + 2SO_2 \leftrightharpoons Fe_3O_4 + 2{\cdot}5S_2$ because the equilibrium depends on the amount of troilite in the system In the solid products which form as a result of the FeS reaction with SO_2 and of the reversible reaction of Fe_3O_4 with sulphur, the presence of pyrrhotite is always noticed; up to 900° with a composition near to Fe_7S_8 and at higher temperatures nearer $Fe_{11}S_{12}$.

A method of fractionation applicable to the Lorraine oolitic iron ores Rouby (*Rev. Ind. Min.*, 1959, **41**, Aug., 662–666) After sampling and crushing, the calcite is dissolved in HCl, and the insoluble matter dried, and separated magnetically, followed by a screen analysis, visual examination under a lens, and chemical analysis.

Concerning the kinetic equations referring to some technical indices of flotation. I. H. Panu and B. Georgescu (*Studii Cercetari Met.*, 1959, **4**, (2), 201–228) By means of certain equations previously derived other equations are now deduced for two other indices of flotation as a function of time, i.e. of the content of useful substances in barren materials, and of the useful content in the early fractions of the concentrate. These equations have been experimentally checked against the flotation of pyrites and kinetic curves have been constructed both for the entire ore and for the differently granulated portions. The experimental results have confirmed the theoretical calculations.

Fatty and resin acids as collectors for iron oxides S. R. B. Cooke and W. Nummela (*US Bur. Mines Rep. Invest.*, 5498 1959, pp.24) Flotation tests on haematite, magnetite, and goethite are reported.

Steep Rock Iron Mines Limited, now concentrating low-grade iron ores W. J. Huston (*Blast Furn. Steel Plant*, 1959, **47**, July, 714–715) Beneficiation has produced two new concentrates with high Fe:Si ratios (10·6:1 and 14·4:1).

Operation of a dithionate-process pilot plant for leaching manganese ore from Maggie Canyon deposit, Artillery Mountains region, Mohave County, Ariz. C. Rampacek, H. C. Fuller, and J. B. Clemmer (*US Bur. Mines Rep. Invest.*, 5508 1959, pp.54).

Ore preparation plant at Aviles J. C. Hart (*Brit. Steel*, 1959, **25**, Aug., 302–307) An illustrated account with flow diagram.

The use of excess air during the ignition of a low-grade sinter mix D. F. Ball (*JISI*, 1960, **194**, April, 479–484) [This issue].

Making of self-fluxing sinter and blast furnace practice with 100% sinter burden K. Kasai and T. Sanematsu (*Tetsu to Hagane*, 1959, **45**, May, 491–499) Finely ground limestone used in sinter obviates fayalite formation and the glassy silicate matrix. To make self-fluxing sinter, precise control of blending is essential; coke breeze should be <5 mm and limestone <3 mm. Satisfactory furnace operation was obtained at Kokura Steel Works with 100% sinter burdens; the coke rate can be reduced to <5000 kg/tonne of iron and the furnace productivity to <1·3 tonnes per day per m^3 of internal volume.—K.E.J.

Results of the measurements of the sintering conditions before and after the reconstruction at the sintering plant, Kokwra Works T. Sanematsu, S. Kiriyama, and H. Toyozawa (*Sumi. Met.*, 1959, **11**, April, 88–97) The plant was reconstructed to increase capacity. Variations in bulk density of the mix show the need for improvement of the charging equipment. Leakage between the strand and fan is reduced from 54 to 35% and flow through the strand increased from 48 to 70%.—K.E.J.

Working of the second sintering plant of KYuGOK during the commissioning period P. A. Lyakhov and L. E. Kunin (*Stal'*, 1959, (9), 776–782) Grinding and blending arrangements, proportioning and conveying, and general conditions of operation as well as faults found in the design and equipment are described. The dust collected is removed as water-borne pulp. The conditions arrived at and recommendations for improvement are given.

The influence of fundamental factors on the sintering process (*BISRA Summary*, 138, 1959, pp.2) A summary of a report on sinter bed operation.

Processing of magnetite ores with particular reference to Salem magnetite S. K. Banerjee and P. I. A. Narayanan (*NML Techn. J.*, 1959 **1**, May, 23–27) A review of methods of pretreatment including sintering.

On the mineralogical content of fluxed sinters N. G. Moleva and P. S. Kusakin (*Trudy. Inst. Metallurgii*, 1958, (2), 187–193) Investigations of sinters of different ferrous and nonferrous ores have shown that lime reacts primarily with silicates. As a result of the reaction of lime with fayalite, the latter decomposes into ferrous monticellite. With an excess of lime, calcium silicates are formed. The phase constitution of lime sinters changes rapidly with the silica content. In sinters with 12–16% SiO_2, CaO reacts with it, forming Fe, Ca, and Al silicates. With a silica content round 7% the low-melting-point liquid phase of the sinter dissolves. Magnetite, and on cooling, calcium ferrites of variable composition crystallize out.

Pelletizing a burden with a proportion of pyrite cinders S. V. Vasilevich and B. L. Lazarev (*Metallurg*, 1959, (2), 4–7) At the NTMK Works, experiments were carried out for the production of fluxed pellets from ore mixtures with pyrite cinders for comparison with the normal sintering process. The pelletizing was carried out in a plate granulator 1000 mm dia. rotating at 12 r.p.m. with both the ore mixture and with the components separately. 100 g. specimens of these pellets and of sintered materials were then lowered 8 m below the charge level into the stack in baskets attached to steel tubes. Results show that the introduction of pellets of pyrite cinders into the burden has less influence on technical and economic indices than has a sintered charge with additions of pyrite cinders.

Increasing the speed of charging conveyors on a sinter plant D. P. Pritykin (*Metallurg.*, 1959, (10), 4–6) In 1951, the sinter plant at Zaporozhstal went into operation with four sinter machines. In 1954, two more were added and output was increased to 750 t/h. In 1956, the feed strands could no longer adequately serve the machines and it was decided to increase the speed of the feed conveyors. Details are given of the high speed operation and automation. Output was increased by 400 t per h and trials showed that, with a conveyor speed of 4 m/s, an output of 1500 t/h can be achieved.—R.S.

Symposium on sinter plants K. S. Loofboro, G. W. Watson, W. O. Bishop, C. P. Frame, and R. W. Adams (*Iron Steel Eng.*, 1959, **36,** June, 101–122) Data are given on the sinter plants of Jones & Loughlin Steel Corp., Cleveland, Ohio, Weirton No.2 plant, new facilities at Inland Steel Co., Chicago, and the layout and design of the Ashland sintering plant.

Steelmen try automation in the sintering process J. E. Oram (*Steel*, 1959, **144,** June 15, 150) The application of automation in the control of the raw material feed system and in the sintering process itself is briefly considered. The use of data logging equipment for correlating process variables is proposed.—A.G.

FUEL—PREPARATION, PROPERTIES AND USES

A study of a simplified theory of gravity concentration in coal jigs R. P. Charbonnier (*Can. Min. Met. Bull.*, 1959, **52,** June, 385–388).

Preheating coal for carbonization M. Perch and C. C. Russell (*Blast Fur. Steel Plant*, 1959, **47,** June, 591–597) A series of trials carried out by Koppers Co. Inc., to investigate the improvement in coke properties obtainable by preheating high-oxygen coals. Improved quality approximately equivalent to the addition of 20–30% low-volatile coal or 5–10% petroleum pitch was obtained, and the heat applied is roughly balanced by the resultant saving in coking time (9 refs).

Coke preparation and the solid-fuel market J. R. Grey and R. J. Newman (*Inst. Gas Eng. Publ.* 549, 1959, May, pp.36) The report deals, in general, with gas coke, largely for domestic uses.

The American coking industry (*BCRA*, 1948, Aug., pp.30) A report of a delegation. **The American coking industry, 1957** (*BCRA*, 1958, June, pp.64) A further report, with a special section on blast-furnace coke.

The B.C.R.A. 15 lb test over for the study of blending F. Frith and R. A. Mott (*BCRA*, 1957, Feb., pp.33) A miniature coke oven is described.

Coke ovens and by-products plant S. B. Sinha Roy and S. N. Sircar (*Tisco*, 1959, **6,** April, 111–126) A fully illustrated account of the Tata installations.

Carbonization of briquets P. M. Yavorsky, R. J. Friedrich, and E. Gorin (*Ind. Eng. Chem.*, 1959, **51,** July, 833–838) The use of a digital computer to assess heat transfer and thermal stresses in the continuous production of form coke for blast-furnace use is described.

Theory and manufacture of shaped coke B. Splíchal (*Hutn. Listy*, 1959, **14,** (6), 473–476) An account is given of the semi-scale production of shaped coke at Kharkov, based on the theory that improved dispersion of the solid constituents in coal in the plastic state during the coking operation can be obtained by applying external heat for an appropriate time, thus enhancing the coking properties of otherwise unsuitable coals (9 refs).

Coke reactivity–II. Study of foundry cokes and comparison with their value in practice A. F. Boyer and G. Durand (*Chim. Ind.*, 1959, **82,** Sept., 309–328) Tests in a cupola showed some correlation with reactivity but size and breaking strength were more important. Size, size after a shatter test, and apparent density are suggested as suitable control measurements.

Physico-mechanical and physico-chemical properties of special classes of blast furnace coke A. S. Bruk, Z. A. Volkova, R. E. Leibovich, Ya. M. Obukhovskii, and V. A. Leites (*Koks i Khimiya*, 1959, (1), 21–24) The quality of the burden components of blast-furnace coke is conditioned by the properties of the different qualities, their non-uniformity as regards lump size and other indices, hardness, strength, reactivity, and degree of preparation. The difference between the various classes of coke for a constant quality of the burden are determined by the thermal and technical properties of the coking process. A classification of cokes by lump size will prove effective towards increasing the properties of the proportion of fuel added to the burden.

AIR POLLUTION AND SMOKE

Air pollution—industry's challenge J. W. Franklin (*Eng. Min. J.*, 1959, **160,** July, 65–75) A discursive review, mainly on the health problem.

Steelmaking processes in relation to atmospheric pollution R. J. Sarjant (*Iron Steel*, 1959, **32,** May, 185–190) Summaries of the nature and amounts of solid pollution from various types of steelmaking plant are given. Dispersion of chimney effluent is discussed, and it is shown that it is possible to calculate within a factor of 2 the rate of deposit to be expected from given conditions of emission.

Clean air from steelworks Koppers Co. (*Engineering*, 1959, **188,** Aug. 28, 111) A note on two electrostatic plants ordered for the Jones and Laughlin Pittsburgh works and for Cornigliano SpA, Genoa.

Fourth colloquium on dust (*Lab. Central des services chimiques de l'Etat, Paris*, 1957, March, 28–30, pp.130) **Study on the present position of some fundamental problems on the techniques of examination of industrial dusts** Membrane filters are reviewed and classifiers discussed and methods of quantitative estimation are considered. **Evaluating the risks of silicosis** (48–77). **Foundry dusts, silicosis-producing potential** Martin (71–73). **Dusts other than silica Studies in the (U.K.) Government laboratory** A. R. Baynes-Cope (78–89). **Practical applications of the methods of study of dusts in protection** (83–100). **Kieselguhr** (84–92). **Portable apparatus for protection against dusts from grinding** A. Gaisne (94–96) **Various papers on the struggle against dust** (101–113). **Documentation** (118–125).

System cleans electric furnace exhaust (*Steel*, 1959, **145,** July 20, 92) A bag filter system is briefly described.

Geometric mean particle size and its application in the sampling of air-borne dust S. Guruswamy and V. S. Narasimhachar (*J. Sci. Ind. Res.*, 1959, **18B,** Aug., 319–323) The method of calculating the parameter and its use in dust sampling work are explained.

REFRACTORY MATERIALS

Refractories for steelworks L. Pompei (*Collana Tecnica, Associazione Italiana di Metallurgia*, **3,** Part I, pp.209) [In Italian] This pamphlet limits itself to a survey of the refractories used in the casting pit of a steel melting shop; lining of the ladle, ingot moulds, down gates, and plug-hole, etc.

A metallurgist looks at ceramics J. E. Burke (*J. Met.*, 1959, **11,** Nov., 740–743) The scope, uses, processing, types, and properties of ceramics are reviewed.

Present state of development in the field of refractory products for the iron and steel industry J. Kratzert (*Neue Hütte*, 1959, **4,** July, 429–423) Characteristics of modern iron and steelmaking refractories, with particular reference to German specifications, are discussed under the headings of firebrick, blast-furnace lining brick, silica brick for open-hearth and electric furnaces, magnesite and chrome-ore-containing brick, and ladle and special refractories, including zirconium silicate.

Standardization of steelmaking refractories M. Thiault (*Centre Doc. Sidér. Circ.*, 1958, **15,** (10), 2061–2066) The results of an enquiry by IRSID at a number of basic Bessemer OH plants into the use of German refractory standards are presented and discussed.

The present state and future prospects of the refractory industry L. Pompei (*Fonderia*, 1959, **7,** Oct., 444–471) The future of the refractory industry and consumption of refractory materials by the most important industries are described, with special reference to Italy. The consumption of refractories in the metal casting and engineering industries is dealt with in detail. Raw materials, supplies, and selling prices are also given. The points are amply illustrated with statistical tables.

Electrolytic magnesia—its production and uses. I H. Cartoux (*J. Four. Elec.*, 1959, Sept.–Oct., 225–228) The production of electrolytic MgO is described with control of resistivity, measure of resistances, resistivity in function of temp. and thermal conductivity, with a diagram of an armoured element (Inconel) installation and table of measurements of resistances.—S.H.–S.

Information on refractories F. Savioli (*Collana Tecnica, Associazione Italiana di Metallurgia*, **5,** pp.80) [In Italian] This pamphlet is designed to give refractory users a description of the properties of the materials available and assist them to choose those best for their purpose. The refractories described include silicate and alumino-silicate refractories, the system $MgO–CaO–Al_2O_3–FeO–SiO_2$, refractories containing rare earth oxides, carbon and graphite, zirconium and carbides, sulphides, boron, and silicides. The use of refractory mortar and ramming material is also dealt with.

Research into the problem of manufacture of high-strength, low-porosity carbon refractories R. Pampuch (*Prace Inst. Hutn.*, 1959, (1), 1–9) Lack of homogeneity is taken as the reason for the low strength of carbon refractories produced by conventional baking processes with organic binders. It was found that direct coking of some coals under correct conditions yields a dense material of low porosity and high strength. This result is achieved by proper control of the process and preparation of the material. A large number of experiments gave optimum preparation for manufacture and the catalysts to be used.

Steel-encased brick triggers increased steel production (*Iron Age*, 1959, **183,** June 11, 137) The use is reported of basic refractory bricks encased in steel sheet and having metal reinforcement, in the construction of OH roofs.

New foamed silica block roof on old electric furnace substantially increases height of heating chamber (*Ind. Heat*, 1959, **26,** June, 1218–1221) The replacement of a 30 in. thick refractory roof by a 6 in. thick roof of fused silica foam blocks in a furnace for firing porcelain enamel is described.—D.L.C.P.

Monolithic refractory constructions in steel plant equipment G. M. Cobaugh and C. R. Hauth (*Iron Steel Eng.*, 1959, **36,** May, 110–116) A review of developments over the past few years. Properties and some applications are described, and recent developments of monolithic refractories are discussed in detail, with particular reference to methods of ramming and fabrication.

Chemical and structural changes taking place in an acid refractory lining of a medium-frequency induction furnace A. Cocco (*Fond. Ital.*, 1959, **8,** May, 175–179) This article describes the use of X-rays and photomicrography to examine an acid refractory after use. Analysis shows a substantial increase in Al_2O_3 and Mn content.

Paper on corrosion effect of steel baths on refractories used in iron and steel making processes A. Cocco (*Fond. Ital.*, 1959, **8,** Feb., 47–51) A study is made using binary and ternary diagrams showing the resistance of various types of refractory to chemical action from steel baths. It is concluded that dolomite refractories are more affected by iron oxides than are magnesite refractories.

A laboratory arc-furnace Z. Andres (*Silikáty*, 1959, **3,** 259–361) The design of a 7 kW three-phase furnace for melting small quantities of MgO is described. Temperatures above 2800°C are obtainable; carbon rod electrodes are used.—P.F.

IRON AND STEEL, GENERAL

Australian steel industry's great advance (*Iron Steel Rev.*, 1959, **2,** April, 1023–1027) A general review, mostly statistical.

Steel industry development (*Iron Coal Trades Rev.*, 1959, **179,** Aug. 21, 91–92) An

account from the Iron and Steel Board Annual Report. Schemes approved and plant completed is listed with notes on technical progress.

Views on the Belgian steel industry P. van der Rest (*Acier Stahl Steel*, 1959, **24**, Sept., 391–394) [In English] The substance of an address to the Board of the Centre Belgo-Luxembourgeois d'Information de l'Acier.

The Broken Hill Proprietary Company Ltd, Australia, Kembla No.2, South Australia and Western Australian Works (*Blast Fur. Steel Plant*, 1959, **47**, Nov., 1169–1182) An illustrated description of these three works, giving data of the plant and capacity, together with a description of the research organization.

Smelting in 1965 F. Manguren Sabas (*Min. y Met.*, 1959, **19**, Feb., 163–167) A survey of the Spanish smelting industry from 1937–1956, with details of equipment and production, is compared, with tables of production in USA, USSR, W. Germany, UK, France, Japan, and Italy; with a brief reference to the current increased production of iron and non-ferrous metals in Spain and forecasts to 1973.—S.H.–S.

Russian steelmaking F. M. Rich (*Iron Steel Eng.*, 1959, **36**, July, 63–66) An account of the visit of an American delegation to Russia, and an assessment of Soviet iron and steelmaking capacities and techniques.

Soviet iron and steel industry (*Engineering*, 1959, **187**, June 19, 797) A general review of post-war development, sinter, and high top pressure operation and steel output.

The battle for supremacy—the Soviet Union leads in raw materials A. Gakner (*Iron Steel Eng.*, 1959, **36**, Nov., 117–124) The raw material sources of the USSR are reviewed, compared with those of USA, and discussed in the light of the present Russian seven-year plan.

The upsurge in the iron and steel industry (*Stal'*, 1959, (11), 961–962) An editorial. Recent advances in production and methods are reviewed.

The development of non-integrated plants in the U.S.S.R. V. O. Chernyavskii (*Stal'*, 1959, (11), 1019–1022) A discussion of the possible economic advantages of erecting non-integrated works to fulfil local requirements.

10 years of the German Democratic Republic: 10 years' iron industry D. Zauleck (*Neue Hütte*, 1959, **4**, Sept., 518–525) The development of the iron and steel industry in Eastern Germany between 1949 and 1959 is described, with comparative data from 1936.

Observations on steelmaking research in the USSR J. F. Elliott (*J. Metals*, 1959, **11**, July, 465–467) An outline of Soviet developments in fundamental research, and in iron and steelmaking techniques, including the use of O_2 in blast-furnace practice, and the continuous casting of steel and vacuum degassing.

The future of ferrous metallurgy in the Russian Federation N. I. Sheftel' (*Metallurg*, 1959, (9), 1–3) A program of development for the seven-year plan outlining measures taken to increase ore extraction, coke production, the automation of 95% of blast-furnace production, considerable increase in converter steel output, and oxygen blowing, casting *in vacuo*, increase in rolled sheet output from 26% to 33% of a much increased total of steel output, in widths up to 2300 mm.

Some prize-winning suggestions at the 12th All Soviet competition for saving power: Report (*Promyshlennaya Energetika*, 1959, (1), 37–41) Prizes have been given for certain devices described below; a cooling system by vaporization for OH furnaces; an induction furnace for mains frequency with cylindrical cast iron crucibles for melting Al alloys; a two-zone electric furnace for sintering solid alloys etc.

India bases its future on steel Kaiser Steel Co. (*J. Met.*, 1959, **11**, Nov., 734–739) Industrial targets set by the Indian Government are outlined, and details of six Indian steel plants are given.

Notes on Chinese Metallurgy L. B. Sokolov (*Chern. Metallurg*, 1959, (4), 151–155) Some interesting statistical data are given on the growth of the industry in China by regions as, for example, blast-furnaces increased from 1954–1957 from 34 to 63, their total volume from 8400 to 35000 m³ and their average size from 246 to 570 m³. The increase of OH steel production was from 1·5 to 15×10^6 t, of converter production from 0·3 to $0{\cdot}5 \times 10^6$ 6 and of electric steel from $0{\cdot}2$–$1{\cdot}2 \times 10^6$ t.

The Chinese iron and steel industry [Anshan Steel Plant] (*Met. Bull.*, 1959, Oct. 2, supplement i–v). An illustrated account of the Anshan plant with statistics, and illustrations of a small blast-furnace and a communal ironworks are given.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG IRON

Margam works. No.5 blast furnace blown-in (*Brit. Steel*, 1959, **25**, June, 205) Dimensions are given and various other notes.

BHP's largest blast furnace (*Chem. Eng. Min. Rev.*, 1959, **51**, July 15, 52–53) A brief illustrated account of the Port Kembla installation.

New blast-furnace and the sintering plant P. K. Chatterjee and P. M. Mehta (*Tisco*, 1959, **6**, July, 129–168) A fully illustrated account of the new expansion project at Tata.

The present stage of development of charging plant in the high- and low-shaft blast furnaces of the East German Republic W. Koch (*Neue Hütte*, 1959, **4**, Nov., 652–662) Charging devices are described and classified. Suggestions for modernization are made. Mechanization and automation are advocated.—L.J.L.

Some design changes in large blast furnaces V. S. Brazhnik and A. I. Shcherbina (*Metallurg*, 1959, (7), 7) This article deals with various projected changes differing from the State designed blast-furnace. These modification deal with lining plates in the throat, blast mains, dust catchers, and cover blower house design, sinter bunkers, etc.—R.S.

Improving the design and equipment of the blast furnace I. I. Korobov, V. I. Surovov, and K. I. Kotov (*Stal'*, 1959, (11), 968–981) Modifications in the design of a furnace at Gipromez in 1928 necessitated by the site are described. Other changes were made during erection and these are discussed. The hearth pad and slag notch designs were modified, also the throat construction with arrangements for inspection, a gas-sealed hopper and oil-sealed big bell rod, and improved charge distributor. Modifications of the metal and slag runners, mud guns and stoves, and other equipment are also shown.

Coal-made iron M. W. Thring (*JISI*, 1960, **194**, April, 484) [This issue].

Practical measures to prevent abnormal wear in a steel mill. II. J. De Vries (*Wear*, 1959, **2**, Aug., 394–396) The blast-furnace top assembly rotating gear has been redesigned as an enclosed worm with bath lubrication. The moulding sand mixer has been fitted with rubber blades. Moulding cylinders in a foundry are lubricated with pads of sponge plastic instead of felt. Rotating table feed discs in a sinter plant have been improved as have the sliding chutes and the dust discharge tubes.

Rapid repair of a blast furnace V. I. Bodrov and A. S. Zalkind (*Metallurg*, 1959, (8), 5) The article describes capital repairs to a blast furnace at Azovstal' in March 1959, whereby total repair period with partial re-building was 36 days instead of the 45 days planned. Repair schedules are given.—R.S.

Proposed furnace design should double iron output Koppers Engineering and Construction Division (*Iron Steel Eng.*, 1959, **36**, Nov., 160, 162) The design and performance are described of a blast-furnace to work with a top pressure of 40 lb/in². It has a hearth diameter of 28 ft, and an estimated output of the order of 4000 t per day.

Blast production for the 1000 m³ blast furnace M. G. Teplitskii (*Stal'*, 1959, (11,) 1040–1045) The blowers originally fitted were of too small capacity. Use of the intensity coefficient of coke combustion to calculate the required blast volume for large furnaces is explained and a new type of rotor for fitting to the 4000–44–1 blower is described. The reconstruction process is set out.

Basic principles of mechanics of fluids in blast furnace practice J. Le Floch (*Mét. Constr. Mécan.*, 1959, **91**, Nov., 819–829) A mathematical survey, with numerous equations, of the part played by fluids in the thermal balance-sheet of pig-iron production.

Blast furnace practice with self-fluxing sinter burden Y. Doi and K. Kasai (*J. Met.*, 1959, **11**, Nov., 755–759) A summary of a paper presented at the 1959 AIME Blast Furnace, Coke Oven and Raw Materials Conference, giving details of the savings in coke consumption achieved at the Kokura steel works, Japan, by 18 months' working with 10% self-fluxing sinter.

The effect of increased basicity of sinter on the productivy of the blast-furnace J. Duda (*Hutník*, 1959, **9**, (6), 205–208) Advantages derivable from a sinter charge of increased basicity are discussed on the basis of recent work carried out in Britain, Czechoslovakia, and the USSR.—P.F.

Effect of preparation of the burden on the yield of the blast furnace H. Kahlhöfer, A. Send, G. Pfrötschner (**Stahl Eisen*, 1959, **79**, Oct. 15, 1461–1471) The Mannesmann works conducted a trial in which a basic burden was gradually altered with respect to the addition of prepared burden, i.e. sinter and screened Minette ore. When charging a burden that contained about 50%Fe-sinter and 23%Fe—screened Minette ore, coke consumption was reduced by 12%, pig-iron yield raised by 7%, and flue-gas dust load reduced by 78 kg/t of pig iron. The altered heat balance is discussed and fully explained. After the trial had been so successful the whole blast-furnace practice was accordingly changed, the results obtained were the same as in the trial.—T.G.

The problem of carbon block linings for blast furnaces S. Zielinski and W. Wozniacki (*Hutník*, 1959, (5), 178–186) The author first considers the effect of the carbon lining on the length of operation of a blast-furnace. Next the physical chemistry properties of carbon blocks are outlined. Finally the character of the deterioration of the carbon blocks and the reasons for this are given. Deductions are drawn in conclusion.

Acid and hyperacid blast furnace working E. Bonnaure and F. Douez (*Centre Doc. Sidér. Circ.*, 1958, **15**, (7), 1447–1463) A description, with operational data, is given of the acid blast-furnace burdening techniques in use at Watenstedt using lean ores, three furnaces working on a CaO/SiO_2 ratio of 1·00–1·10, and a fourth on a ratio of 0·50–0·60. The article concludes with a brief description of the sintering and pig iron granulation techniques in use at Watenstedt.

Smelting of Bakals ores in blast furnace burdens with a maximum proportion of siderites V. V. Mikhailov, B. Z. Kudinov, V. I. Zhuchkov, A. V. Chentsov, and L. L. Osinovskikh (*Trudy Inst. Metallurgii*, 1958, (2), 61–66) It is possible to arrange the production of fluxed agglomerates of siderites and brown iron ores with partial or nearly complete elimination of lime from the burden. The agglomerate with additions of granulated siderite below 6 mm diameter, is harder and more reducible than that of brown iron ore only. It is possible to produce conversion iron with 70–80% siderite. The temperature of the air blast should be the highest possible.

On the reduction of magnetite in the blast furnace R. Zoja, L. P. Bicelli, and G. Gianasso (*Met. Ital.*, 1959, **51**, March, 89–93) A study is made of the products obtained by reducing magnetite in the blast-furnace. Test pieces show four concentric areas in which, using X-rays, the following constituents were located, from interior to exterior, Fe_3O_4, Fe_3O_4+FeO, FeO, FeO+Fe, and Fe. The conclusion is that at least as far as very porous material is concerned reduction is achieved by the CO which is diffused through the mass and not by diffusion of the iron through the solid phase as previously thought.

Note on blast furnace operation at a very slow rate E. Noël (*Centre Doc. Sidér. Circ.*, 1959, **15**, (7), 1465–1472) Trials at Ougrée are described in which iron production was retarded by supplying cold blast at the lowest feasible pressure. The trials were carried out in 1938.

Aerodynamical resistance of the layers composing the burden materials in blast furnaces A. A. Chechulin and V. G. Pavlov (*Chern. Metallurg.*, 1959, (4), 23–29) Tests were carried out with various burden components of

definite lump size and their mixtures in cylinders to measure permeability. From these tests relations were deduced by means of which the aerodynamic resistance of a burden can be calculated. Experiments have shown that between calculated and actual measurements a deviation of ±12% may be expected.

Rig drills blast-furnace tapholes (*Iron Steel Eng.*, 1959, **36,** Nov., 151) A converted coal drilling rig, used by the Pueblo plant of Colorado Fuel and Iron Corp. for drilling blast-furnace tapholes, gives increased safety in operation.

The 'NEU' valves, blowers and compressors with rotary impellers M. Dennis (*Centre Doc. Sidér. Circ.*, 1959, **16,** (5), 1155–1174).

Wear of blast furnace carbon hearth pads Yu. A. Popov and V. I. Markin (*Stal'*, 1959, (11), 982–985) The wear of a carbon-rammed chrome-magnesite pad is described, and a tracer study which was also made. The use of carbon blocks in the central part of the pad is not advised. In an editorial note, low productivity and erratic operation are indicated as one cause of the low hearth wear.

Development of a new horizontal-flow, plate-type precipitator for blast furnace gas cleaning B. R. Berg (*Iron Steel Eng.*, 1959, **36,** Oct., 93–101) This type of precipitator, designed by Svenska Flatfabriken, employs a water flushing system of cleaning, so introduced and distributed that large precipitator units can be built and operated efficiently. Design and operational results are discussed.

Ironmaking in the new China: Ancient methods help to raise output (*Iron Coal Trades Rev.*, 1959, **179,** Sept. 11, 294–295; from *Metallurg*) Primitive crucible, cupola, and blast-furnace operations are described.

Nitrogen quench of experimental blast furnace J. J. Bosley, N. B. Melcher, and M. M. Harris (*J. Met.*, 1959, **11,** Sept., 610–615) To gain knowledge of the blast-furnace process, the contents of the US Bureau of Mines experimental blast-furnace were quenched with a nitrogen atmosphere, and sampled extensively for analysis. The procedure adopted is described, and some preliminary results of chemical and petrographic analyses are reported.

The reduction of iron oxide, in particular wustite O. Knacke (*Arch. Eisenh.*, 1959, **30,** Oct., 581–584) Reduction of hematite and magnetite proceeds stepwise. The elementary processes are: solid body diffusion in magnetite and wustite, the heterogeneous reaction $FeO+H_2 \rightarrow Fe+H_2O$ (in H_2 reduction) and porous diffusion. The following expression for the last named reaction is derived: $i=131 \cdot \exp(-15200/RT).n_{H_2}$ [mol. $0/cm^2.s$]. The interaction of heterogeneous reaction and solid body diffusion is discussed (21 refs).

Reduction of iron oxide by carbon monoxide, hydrogen and their mixtures L. N. Rudenko and S. T. Rostovtsev (*Chern. Metallurg.*, 1959, (4), 3–12) The relation between the rates of reduction of the iron oxides by H_2 and by CO changes according to the conditions and the stage of the reaction. In the first stage (reduction of Fe_2O_3 to Fe_3O_4) CO gives a more rapid rate of reduction at low and moderate temperatures (up to 600°). In the second and third stages (Fe_3O_4 to FeO and FeO to Fe) hydrogen has kinetic advantages. A mixture of H_2 and CO results in a pattern of reaction kinetics depending on the temperature.

Factors influencing and improvements in thermal efficiency in iron and steelmaking furnaces G. Arregui Echeverria (*Met. Elect.*, 1959, **23,** Oct., 246–247, 249–253, 255–258) Thermal balances are determined for several cases, including a blast-furnace, and factors influencing thermal efficiency are analysed and discussed in detail.

DIRECT PROCESSES

Direct reduction processes. A review J. MacKenzie (*Iron Steel*, 1959, **32,** Sept., 442–444) The main processes are classified and described in outline.

Direct reduction of iron ore A. Roos (*Mét. Constr. Mech.*, 1959, **91,** Nov., 811–917) Conventional steel processes and principles of direct reduction on an industrial scale are examined and reference is made to the practical means of reducing N. African iron ores resulting from use of Sahara gas supported by Govt. finance.—S. H.–S.

Direct reduction: the flash steel process J. J. Burke (*J. Metals*, 1959, **11,** Nov., 747) In this process pellets or briquettes are preheated to 1400°F fed into the top of a furnace, where they are met by a rising stream of a CO–H_2 reducing gas mixture. They fall slowly through the gas, are reduced, and liquefy to 1%C steel. Some details of the process, including economic factors and a heat balance are given.

The position and prospects in the development of methods of direct iron extraction I. L. Lur'e (*Stal'*, 1959, (11), 1048–1054) A review of the reasons (shortage of strong coke and good scrap) for, and methods that might be used (sponge iron, gaseous reduction, or direct steel processes) in areas with poor ore and no coal is given. Processes being worked or developed experimentally are surveyed, not in the USSR only.

The Strategic–Udy direct reduction process M. J. Udy and R. A. Blackburn (*Iron Steel Eng.*, 1959, **36,** Nov., 109–116) Features of the process are described and illustrated, a detailed example of material and energy requirements is worked out, and a table showing typical manufacturing costs is reproduced.

A new direct iron process in relation to ore and steel production H. Freeman (*Can. Min. Met. Bull.*, 1959, **52,** Aug., 529–531) A rotary kiln method working at Cap-de-la-Madeleine producing iron pellets is described.

Processing of low-grade iron ore using petroleum and natural gas P. E. Cavanagh (*Eng. J.*, 1959, **42,** Aug., 84–87) A review of direct processes concluding that the blast-furnace is, in general, the most economic unit and suggesting conditions under which direct reduction might be able to compete (under Canadian conditions).

PRODUCTION OF STEEL

Lukens steel completes expansion programme at cost of $33,000,000 (*Blast Furn. Steel Plant*, 1959, **47,** June, 598–600) A description is given of the recently-completed expansion of the steelmaking and rolling capacity at Lukens Steel Co.

United States Steel's Geneva works T. J. Ess, G. W. Madsen, L. Tofft, E. W. Hunziker, J. V. Mazurie, M. E. Strate, and M. Matekovic (*Iron Steel Eng.*, 1959, **36,** June, G2–G28) The layout, iron and steelmaking and rolling plant, and utilities and services of this modern works are described in detail, together with some data on the nearby Ironton plant.

Durgapur steel works and foundry (*Found. Trade J.*, 1959, **107,** Sept. 3, 101–103) A brief description.

A look at Russian steels A. B. Tesmen (*Met. Progress*, 1959, **75,** June, 101–105) Russian development in carbon and alloy steels, and the nomenclature employed are reviewed.

Refractories and the oxygen steelmaking process D. W. N. Pitts (*Refract. J.*, 1959, **35,** Aug., 248–252, 254–255) A review of open-hearth, electric arc, and oxygen converter conditions.

The role and behaviour of carbon in the formation of steel K. D. Majumder (*Iron Steel Rev.*, 1959, **2,** April, 1017–1021) The state of C in steel and the general effects of composition and heat treatment are discussed.

Oxygen methods of steel production D. L. Bryant (*Castings*, 1959, **5,** June, 9, 11, 13, 15, 17) A review.

What does tonnage oxygen cost? S. Katell and J. H. Faber (*Chem. Eng.*, 1959, **66,** June 29, 107–110) Estimated costs for a 500 t/day plant under US conditions are given.

Steel keeps pace in the space race (*Steel*, 1959, **144,** June 29, 88–93) Five research projects of the United States Steel Corp. are described: an experimental OH furnace, the Nu-iron process, vacuum remelting, vacuum casting, and oxygen steelmaking.—D. L. C. F.

Some problems concerning small Bessemer production L. K. Grakhov and V. A. Fuklev (*Lit. Proizv.*, 1959, (6), 20–22) A discussion concerning production of converter steel with O_2 blowing. With a high enough temperature of the metal, favourable conditions are brought about for the oxidation of carbon and during the metal boil in the bath. Lowering the quantitative role of Si and C as sources of heat for the bath, the analysis of experimental data results in the conclusion that the increase in the temperature of the bath from the oxidation of 1%Si is larger by a factor of 2–2·5 than that resulting from the oxidation of 1%C.

Blowing steel with dry air J. B. Bridges and G. L. Meeter (*Mod. Castings*, 1959, **36,** Aug., 25) Results of stirring or blowing steel heats with dry air/O_2 mixture showed that there were no harmful effects, and no appreciable N_2 pickup, and that the temperature generally drops during the blow.

Increasing the weight of the converter charge at the 'Krivorozhstal' ' Works B. E. Gurevich (*Metallurg*, 1959, (3), 19–21) The optimum specific volume of a converter has been found to be 1·0–1·1 m^3/t of pig iron with O_2 blowing from above. Experimental melts with increased charge have been carried out. Each melt was tapped into five instead of four ingots. The results show that by increasing the charge by 20% the productivity of the converters increased 10–18%. In blowing the increased charge the refinement of the bath from injurious impurities is slightly facilitated and the yield improved. Converters with a small ratio of height to diameter (less than 2) with small baths are less useful for top oxygen blowing.

The emulsification of slags by blowing and the contamination of converter steel V. I. Baptizmanskii (*Chern. Metallurg.*, 1959, (4), 31–43) Blowing causes an energetic mixing of slag and metal accompanied by the formation of a slag emulsion and the contamination of converter steel not only in the liquid but also in the solid condition. Converter steel differs from OH steel by an increased amount of inclusions. Experiments have shown that this contamination is related to the position of the lance. In blowing from above, if the nozzle is over the slag–metal line, a certain amount of impurities consisting of slag particles is blown into the metal.

Observation of the state of bath and slag in converters during blowing H. Vöge and E. Eickworth (*Stahl Eisen*, 1959, **79,** Nov. 12, 1715–1722) The physical state of the bath and slag in a converter is highly dependent on the temperature, and studies were made of which factors have the greatest influence on the temperature, particularly before dephosphorization. The Si content of the pig iron had the greatest effect, whereas the depth of the bath appeared to have no influence. It was also found that solid iron crystals precipitate, and this earlier the lower the Si level of the pig iron, unless the bath was extremely hot. At the time when it is formed the slag is in the solid state and becomes liquid when dephosphorization begins, i.e. at about 1500°C. It is shown that the liquidus temperatures in low-Si irons are up to 70°C higher than the bath temperature.—T. G.

The use of oxygen in the converter shop at Krivorozhstal' S. G. Afanas'ev, M. M. Shumov, Z. D. Epshtein, F. F. Ryazanov, G. N. Kozin, and I. S. Kukuruznyak (*Stal'*, 1959, (9), 787–792) The shop and the converters and other equipment are described. Considerable variations in the pig iron composition were observed and this made consistent working difficult. Blowing equipment and various trials with it are described and working figures are quoted. Increase of charge weight to 50 t is recommended and water-cooled flues and waste-heat boilers should be installed.

100-ton converter for oxygen blowing A. I. Pavlov and A. A. Perimov (*Metallurg*, 1959, (8), 17) This short article refers to the Russian State Steel Planning Council's design for a 100-t converter top-blown with oxygen. Design drawings are included and a description of the steel-making shop to house such converters is given. Auxiliary equipment is described. The refractory lining suitable for this process is also described.—R. S.

A converter-type ladle for oxygen blowing P. L. Stolpchenko (*Lit. Proizv.*, 1959, (1), 48) The melting of low and high-alloy cast irons, especially small melts, is laborious or even impossible in cupola furnaces. A description is given of the adaptation of a 1-t drum-type ladle for melting a charge of 300 kg special

iron. For this charge, up to five ganged bottles of oxygen are fed through a pressure regulator and through a 6–8 mm pipe into the bottom of the ladle for decarburization of the charge and to raise the temperature of the iron to 1550–1600°C. Where no cold additions are made to the charge, oxygen consumption falls to 1·5–2 m³. Pot linings last for 30–40 melts, but the life of the lining of the oxygen blowhole is only 4–5 melts.—M.T.

Lining life in basic converters top blown with oxygen S. I. Lifshits (*Stal'*, 1959, (9), 793–795) Factors affecting refractory life are discussed and it is concluded that Si content should be low (0·2–0·3%) and preliminary desiliconizing units should be fitted, increasing SiO_2 in the slag is also an adverse factor as is reduction of slag basicity below 2·5 and superheating of the metal. Accelerating slag formation and reducing bath diameter are also favourable. The editor adds that ore preparation should also be improved.

Development and present position of the LD process O. Cuscoleca and K. Rösner (*Radex Rundsch.*, 1959, Oct., 621–628) A review of the development of the process includes details of converter design and refractories, fume disposal, and the use of the LDAC process for high-P hot metal (13 refs).

Modifications of the LD-process with high-phosphorus irons J. Bečvář (*Hutník*, 1959, **9**, (6), 185–189) Recent developments which have facilitated the utilization of basic Bessemer iron in the production of converter steel are reviewed, and in particular the advantages of the OLP (oxygen-lance-poudre) method developed in France, and the OCP (oxygène-chaux-pulverisé) developed in Luxembourg, over the LD-method are considered.—P.F.

Scientific and technical considerations relating to the use of oxygen in steel manufacture R. Durrer (*Problemas de la Industrie Siderurgica y de la Transformation de Hierro y Acero en America Latina*, 1957, (2), 70–72) The use of oxygen in refining steel by the converter and OH processes is considered. **Manufacture of converter steel by means of surface blowing** H. Trenkler (72–81) A detailed description is given of the method and manufacture of steel by the LD process, its properties and applications. **The Stora Kal-Do process for manufacturing steel with oxygen in a rotary apparatus** B. Kalling and F. Johansson (86–88) A short account of the characteristics of the Stora Kal–Do process as operated at Domnarvet. **Technical-economic aspects of the use of oxygen in the manufacture of steel, especially in the case of the ordinary converter** A. M. Clark and J. L. Harrison (88–99) The use of oxygen-enriched blast and of oxygen-steam and oxygen-CO_2 mixtures is discussed, and reference is made to the use of oxygen in OH practice. **Qualities of the steels obtained in converters blown with oxygen** K. G. Speith (100–111) The chemical and mechanical properties of oxygen-blown converter steel are examined in detail, and compared with similar steels made by the OH process. Particular attention is given to rimmed steels. **The oxygen-blown converter in Latin America** G. Bulle (115–121) Latin American experience in the use of oxygen-blown converter processes and probable lines of development are discussed. **New regulating instruments for the manufacture of steel in the converter** P. Leroy (121–129) Examples of the use of instruments for research, control of blast and temperature, and the end-point of the blow are given and discussed. **The problem of high-grade steels in Latin America** T. Niemeyer (217–220) The production and application of structural and special steels are discussed, with special reference to Latin American manufacture and requirements. **The production of high-grade steels in Mexico** F. G. Vargas (221–225) The high-grade steelmaking capacity and consumption of Mexico are outlined. **High-grade steels in Brazil and Chile** F. Riekeberg (225–238) The high-grade steelmaking capacity requirements and manufacturing methods in Brazil and Chile are described in some detail.

The manufacture and properties of basic oxygen steel for wire products H. B. Emerick and S. Kreisberg (*Wire Wire Prod.*, 1959, **34**, Oct., 1331–1335, 1339) Experience at the Jones & Laughlin Aliquippa plant in the use of the LD process, particularly for steel for wire manufacture is reviewed.

Modern processes for the production of steel. The LD process F. Herrero de Egaña (*Min. y Met.*, 1959, **19**, Feb., 149–161) The application of the LD process to the plant of Altos Hornos de Vizcaya is discussed, and its operation compared with its uses in French and Japanese plants. The construction of the Yawata furnace is described in detail; and the LD process is compared with the OH.—S.H.–S.

Refining of irons, using pure oxygen and powdered lime. IRSID–OLP process B. Trentini and M. Allard (*Rev. Mét.*, 1958, **55**, Dec., 1195–1208) A new process for iron refining is described, using powdered lime and pure O_2. It is claimed that basic Bessemer irons can be treated systematically and economically, resulting in low P, S, and N contents. The process is said to be flexible and can be applied to all phosphoric irons, including hematites.

Measuring and control plant at the experimental converter of Phoenix Rheinrohr at Duisberg, Ruhrort K. Ewe (**Regelungstechnik*, 1959, **7**, (7), 248–253) The converter uses the PL-process in which P removal is accelerated and in the later stages the converter is tilted and surface blown. Gas flow, outlet gas analysis and particularly control of oxygen are described.

The volatilisation of iron (II, III) oxide, manganese (II, III) oxide and chromium (II, III) oxide H. von Wartenberg (**Arch. Eisenh.*, 1959, **30**, Oct., 585–587) Volatilization trials are described on eutectic composition oxide mixtures, as a contribution to knowledge of the reactions taking place in the production of brown fumes in steelmaking processes.

The use of open hearth sinter B. G. Petukhov and P. K. Morokov (*Metallurg*, 1959, (3), 11–15) The use of sinter in the OH charge instead of iron ore does not complicate melting. Metal quality does not suffer. The yield of good rails of the 100 lb per yard type based on sinter charge in the OH is 94·16% while the same figure for rails made on an iron ore charge was 93·63%. Sinter can be used for all grades of steel, either alone or mixed with iron ore. In view of the somewhat lesser oxidizing capacity of sinter, its consumption in the charge is rather greater (7–10%) than the consumption of iron ore. No violent reactions occur and a fluid slag is obtained during melt-down, though the amount of first slag removed is 5–10% higher than normal. Dephosphorization improves, consumption of limestone and lime and bauxite is reduced, and tap-to-tap time cut by 20 min. for rimming steel and by 35 min. for rail steel.—R.S.

The influence of the thickness of the plates between bricks on the strength of roofs E. M. Tsygankov and M. F. Patnikov (*Metallurg*, 1959, (4), 17–19) It has been established that plates between the magnesite chromite bricks must be between 0·5 and 0·7 mm thick. These plates ensure good welding of bricks to form a monolithic roof, they decrease stresses and reduce heat losses. The use of bricks with specially shaped plates reduces wear and appreciably increases the roof strength.

A progress report: basic construction in the open-hearth A. H. Sommer (*J. Met.*, 1959, **11**, Sept., 623–627) The history of the development in basic open-hearth construction from German progress during the 1939–45 war is outlined, with special reference to US practice. Suspended and sprung all-basic roof designs are discussed.

Basic arches and roofs of metallurgical furnaces L. Hütter (*Radex Rund.*, 1959, Oct., 629–639) The advantages of basic roofs are discussed, and choice of brick and roof design are considered.

Basic open-hearth roofs. Developments in design and quality in recent years K. Leitner (*Centre Doc. Sidér. Circ.*, 1959, **16**, (5), 1107–1121) Subjects discussed are brick shapes, development of semi and totally suspended roofs, with examples, and a discussion of problems which have arisen in practice.

New equipment for O.H. furnaces I. I. Vinioli (*Metallurg*, 1959, (9), 23–24) New apparatus is described for removing slag from the mixer, also a new ingot stripper.

Bifurcation of open-hearth furnaces C. G. Campbell (*Iron Steel Eng.*, 1959, **36**, Oct., 126–128) Sixteen furnaces were bifurcated and a new one installed at the Colorado Fuel and Iron Corp., Pueblo, without interrupting production, the program being completed in 11 months. Details of the procedure adopted are given.

Burning in open hearth bottoms in Kazakhstan N. Ishmukhamedov (*Metallurg*, 1959, (2), 19–20) Two methods of burning in bottoms in Kazakhstan are described. The first uses magnesite layers (70–75%MgO). Each layer is 20–25 mm thick and burning in time is prolonged so as to achieve regeneration of the periclase grains. The second method uses layers containing fluxes (slag or millscale). The second method is more progressive. Further details are given of experience of burning in bottoms in Kazakhstan steelworks and how these methods have cut down repair times.

PRODUCTION OF FERRO-ALLOYS

Production of compact carbon-free ferrochromium and metallic manganese by vacuum treatment S. I. Khitrik, N. Ya. Neimark, V. I. Nikolaev, and M. I. Gasik from a symposium, *Primenenio Vakuuma v Metallurgii*, 1958, 112–122) Vacuum treatment eliminated gases and blowholes from Fe–Cr and Mn ingots. The development of the process as carried out at Zaporozhe and the results obtained are described. Mn yield was increased 5–20% and Fe–Cr yield 3% with a 25% reduction in the consumption of packing material. Inclusions are also reduced.

Development of the ferro-alloy industry in S. Africa (*J. Four. Elec.*, 1959, Sept.–Oct., 217–218) A short review of the industry from the first 150 t/day furnace in Natal in 1926, covering development of African Metal Corp. (AmCOR) Ferrometals Ltd, and Ferroalloys Ltd, to the present day, with reference to the handicap of long freights on raw materials. Tonnage for two plants now operating is expected to reach 120 000 pa in 1960.—S.H.–S.

The technical-economic comparison of the production of low-grade ferro-silicon by blast furnace and electrothermal methods S. A. Livshits and I. A. Radchenko (*Stal'*, 1959, (9), 846–849) It has been decided to replace blast-furnace ferrosilicon production by an electrothermal process at Chelyabinsk. The calculations on which this was based are challenged, and costs and other figures are produced to suggest that the blast-furnace process could use lean ores unsuitable for electrothermal use and scrap unsuitable for OH working, so giving economic advantages.

Remarks on the manufacture of ferro-vanadium and pure titanium E. Schwartz-Bergkampf (*Radex Rundsch.*, 1959, Oct., 660–664) The importance and occurrence of V and Ti ores are reviewed, and methods of concentration and manufacture of Fe–V and pure Ti are considered (20 refs).

FOUNDRY PRACTICE

Method of obtaining castability and maximum field service from cast products J. W. Beckham (*Mod. Castings*, 1959, **36**, July, 43–46) A method is discussed, with examples, of combining maximum castability with minimum stress concentration in designing cast shapes. The use of experimental stress analysis in developing casting design is described.

British Steel Castings Research Association: Research (*BSCRA 6th Annual Rep.*, 1959, 9–17) Work on O_2 injection, refining slags, foundry processes, plant engineering, and industrial health is briefly outlined.

6085 foundries, their products, processes and location (*Foundry*, 1959, **87**, Aug., 62–64) A table giving the geographical distribution of the different types of foundries in America and Canada is presented and trends are discussed.

The importance of town gas in foundry practice—2 J. Ward (*Ind. Gas*, 1959, **22**, June, 27–32) Uses for producing hot air, drying ladle linings, ladle heating, making spheroidal graphite iron, annealing, and space heating are noted.

Don't alloy your iron with water F. L. Rietveld (*Mod. Castings*, 1959, **36**, Aug., 29–30)

The automatic moisture control system in use at a Midwest foundry blast system is described, in which moisture is maintained at 3 grains/ft³.

The foundry in the car and allied industries I. Fauquembergue (*Fonderie*, 1958, **153,** Oct., 449–465) Cast ferrous metals used in the car industry are discussed. Improvements in dimensional precision are compared when using investment casting, Shaw process, Marcast, Microcast, and similar methods. Results are analysed statistically and this is followed by remarks concerning static, dynamic, and pressure casting. The melting and casting of special ferrous metals, such as spheroidal graphite cast irons, is described. Some modern methods of testing are summarized.—R.P.

Surface finish of iron castings J. Gittus (*Iron Steel*, 1959, **32,** Sept., 445–449) A numerical relationship is established between surface appearance and two methods of measuring surface roughness, and the effects of metal P content and pitch content of the sand on roughness are assessed.

Foundry work in the V.I. Lenin Steelworks V. Koutecký (*Slévárenství*, 1959, **7,** (5), 167–169) On the occasion of the 100th anniversary of the Lenin Works in Pilsen—previously the Škoda Works—the history of its foundries is reviewed and some interesting examples of castings made during the period between the two World Wars are given.—P.F.

The production of machines and equipment for foundries J. Hykel (*Slévárenství*, 1959, **7,** (5), 169–172) The design and use of various types of moulding, core-blowing, grinding, and other machines of Czechoslovak manufacture are discussed.—P.F.

Report on Swedish establishments A. McLean (*Brit. Found.*, 1959, **52,** Sept., 412–417) Swedish industrial, research, and teaching establishments connected with the foundry trade are described.—A.D.H.

Foundry for ingot moulds (*Engineering*, 1959, **188,** Aug. 28, 109) A note on the new Dowlais Ironworks foundry.

The electric steel foundry of Soc. Stein & Roubaix at Lannoy (Nord) (*J. Four. Elec.*, 1959, **5,** 241–242) A brief description.—S.H.–S.

Survey of the Hallsworth automatic moulding system H. B. Hallsworth, R. D. Mills, and P. Spear (*Found. Trade J.*, 1959, **107.** Aug. 20, 45–51) An illustrated account with a section on economics.

Packaged foundries: A survey of the Hallsworth automatic moulding system H. B. Hallsworth, R. D. Mills, and P. Spear (*Iron Steel*, 1959, **32,** May, 191–193, 196; June, 335–337; July–Aug., 389–390) An account is given of the development and technique of the Hallsworth automatic moulding system, in which small, easily handled moulding boxes with automatic equipment are necessary, the arrangement being centred on an automatic moulding machine. This machine and its sequence of operations are described in this section. Details of sand metering and edge tucking procedures, squeezing, stripping, and scraping, coring and mould conveyors, and the pouring arrangement are given. Sand-processing and the economics of the system are finally described.

The Hallsworth moulding system Rubery Owen & Co. (*Auto Eng.*, 1959, **49,** July, 275–281) Automatic units for the equipment of complete foundries or for the mechanization of existing foundries are described. The moulding machine, conveyor system, and typical products are illustrated. Sand reconditioning is included.

Diversity of production on Tees-side (*Found. Trade J.*, 1959, **106,** June 11, 685–687) A description of local foundries and other works in conjunction with the visit of the I.B.F.

Foundries in East Africa W. J. Roscrow (*Foundry Trade J.*, 1959, **106,** June 4, 645–648) Sources of raw materials are included.

Industrial engineering for the small foundry. A practical approach F. E. Noggle (*Mod. Castings*, 1959, **36,** July, 51–61) A work measurement plan suitable for application to a foundry with about 50–100 employees is developed.

New automation and mechanization devices A. A. Dubasov (*Lit. Proizv.*, 1959, (7), 21–23) A two-position sand blowing machine is described for core making. Another machine for knocking out the castings is in operation at the Stalingrad tractor works and a few other similar devices at other foundries are described.

Automation of production at the 'Krasnyi Aksai' Foundry N. I. Durnev (*Lit. Proizv.*, 1959, (7), 23–24) A short report regarding mechanization of loading and removing the charges on conveyors, automation of knocking out mould boxes and of transport.

Choosing optimum parameters for vibration and power for cams driving knocking-out appliances L. F. Liokumovich (*Lit. Proizv.* 1959, (7), 24–28) A mathematical analysis for calculating amplitude, and frequency of vibrations and also the power for driving the cams of the knocking out appliances. The theoretical results have been tested experimentally and found to represent optimum values.

Mechanisation in the coremaking shop W. Gesell (*Giesserei*, 1959, **46,** Dec. 3, 958–960) Possibilities of mechanization are considered, with reference to plant operations using small quantities and few types of sand, and the mechanization of works practice using the core-shooting machine.

Ways of reducing labour requirements in the foundry (*Lit. Proizv.*, 1959, (5), 1) In conformity with the decisions of the 21st Congress, the amount of non-ferrous and iron castings will amount to 21×10^6 t in 1965 which will exceed by more than 10% the USA output in the last decade. A number of suggestions are made for the industry in general to streamline production and improve a number of processes.

Six-electrode arc melting furnaces S. Arnold (*Iron Steel Eng.*, 1959, **36,** May, 185–192) The advantages of six-electrode elliptical furnaces for the probable future development of large melting units are discussed. These include better energy distribution, lighter electrodes, and increased refractory life.

Melting iron in the induction furnace M. B. Hartman (*Foundry*, 1959, **87,** Aug., 98–103) To melt high-carbon iron for centrifugally cast liners and bushes a Californian foundry selected a tilting 125 kW induction furnace. Reasons for this choice are discussed.—A.G.

Melting steel in acid electric arc furnaces J. Plachý (*Slévárenství*, 1959, **7,** (6), 213–215) The introduction of melting in the acid arc-furnace to replace the original basic melting practice was found to result in increased productivity and considerable savings. The acid method is best employed if scrap is fairly abundant. Details of the melting technology used in the Stalingrad Foundries in Prague are given.

The production of S.G. iron by direct treatment of blast furnace pig iron G. A. Pisarenko, S. G. Guterman, P. V. Gubchevskii (*Lit. Proizv.*, 1959, 1), 12–13) Experiments were carried out at the Magnitogorsk Iron and Steel Works on the direct treatment of conversion pig iron in the hot metal ladles with metallic Mg or Si–Mg alloy (Mg content 15%). The furnace casting temperature was 1390–1410°C, and the modification temperature 1350–1360°C. Specimens of modified and unmodified irons were taken. Best results of tests of mech. properties were obtained from iron modified with Si–Mg alloy, since increased Si prevented the formation of cementite which could not be removed from the other irons by heat treatment. Likewise the metal produced with the use of this alloy had much less tendency to growth and greater resistance to the formation of oxide layers. It is suggested that the method should be considered for the production of ingot moulds, rolling mill rolls, and moulds for casting them, slag pots, etc., thereby increasing their life.—M.T.

Some mechanical characteristics of cast iron R. M. O. Weinbaum (*Bol. ABM*, 1959, **15,** July, 573–582) The relations existing between certain mechanical properties of cast iron and those of steel are compared.—S.H.–S.

Brazilian steel foundry expands melting capacity (*Foundry*, 1959, **87,** 68–69) Brief mention of this expansion program of Acos Villares which includes a third electric arc furnace of 15-t capacity and a 2000-t hydraulic press.—A.G.

Refractory concrete in foundries E. Hammond (*Found. Trade J.*, 1959, **107,** Sept. 17, 169–178; Sept. 24, 203–210) The properties of refractory concretes such as are used for monolithic construction are given, especially thermal properties and resistance to corrosion at high temp. Methods of construction and installation are described and illustrated for furnaces of various types. Advantages of castable refractories in electric, fuel-fired, and reverberatory furnaces are discussed. In general high-duty refractories are not widely required in foundry installations.

What makes cast iron 'high quality'? J. Obrebski (*Metalw. Prod.*, 1959, **103,** Aug. 7, 1203–1206) Properties associated with 'high-quality' irons are noted and production, composition, inoculation, heat-treatment, and microstructure are briefly discussed as factors in obtaining the standards required.

Selecting the cast iron for cylinders for motor car engines D. P. Glukhov and S. A. Petukhov (*Lit. Proizv.*, 1959, (7), 16–17) By additions of Ti and Cu, resistance to corrosion increases appreciably. The structure improves, the graphite becomes finer and the amount of ferrite is reduced from 15–20% to 2–3%. The improvement in the structure reduces mechanical wear and additions of copper increase resistance to corrosion.

Phosphorus and titanium in sulphur cast iron V. P. Chernobrovkin, A. A. Dobryden', V. S. Belyaev (*Trudy Inst. Metallurgii*, 1958, (4), 113–121) Additions to the normal sulphur cast iron of up to 1% of P and up to 0·5% of Ti only significantly lower the temperature of the eutectic transformation, although the influence of these elements is individually different; phosphorus displaces the temperature lower and Ti higher. The study of the linear shrinking and the metallographic analysis shows that Ti–P irons are hardened by S and must be classed in the pearlitic category.

Concerning the replacement of ductile iron by magnesium inoculated iron L. Sofroni and C. Cosneanu (*Studii Cercetari Met.*, 1959, **4,** (2), 139–179) Some aspects of the problem of substituting Mg-inoculated iron (spheroidal graphite and white irons) for ductile iron, are considered. A method for producing on an industrial scale s.g. iron of a constant composition is described, and of raising the pouring temperature for thin-walled castings. From a comparative study of properties of castings a method of calculation was evolved for determining the optimum shape of the pouring gate and of the dead head according to the cross-section of the castings and of the structure of the iron.

Concerning the mechanism of the process of liquid inoculation M. M. Turbovskii (*Chern. Metallurg.*, 1959, (3), 101–106) The chemical compositions of chilled and grey cast irons and of a cast iron obtained with liquid inoculation have been investigated over a considerable period. The inoculation was carried out by addition of calculated amounts of liquid grey iron to chilled iron. The chilled iron was used for the production of forgeable castings and the grey iron for normal castings. Both irons were melted in a cupola. The experimental findings prove that inoculation with solid additions differ slightly from those obtained with liquid additions. With solid additions, the loss of inoculant occurs as a result of the coalescence and floating to the surface of the oxidation products, while with liquid addition it takes place by diffusion and relative equalizing of the composition and by the solution of the small graphite inclusions which occur. To avoid this loss the large castings may be directly inoculated with liquid additions in the moulds.

Malleable cast iron R. Roman Martinez (*Inst. Hierro Acero*, 1959, **12,** April–June, 94–205) A review of the historical development of malleable iron production, types manufactured and their properties, casting techniques and defects, and their applications of malleable castings.

Additions of ferro-silico-zirconium to molten grey iron P. Détrez (*Fonderie*, 1958, Aug., 374–384) Additions of Fe–Si–Zr during three methods of melting are described. The mechanical properties, micro-structures, and uses of the resulting castings are discussed in detail. The final content has to be related to section thickness (12 refs).

Spheroidising of graphite in high carbon iron

by calcium silicide M. Maruyama and M. Ito (*Imono*, 1959, **31**, June, 576–582) Above 1500°C, over 10%Ca–Si, stirred in, was needed to produce spheroidal graphite. At 1400–1440°C, over 6% was needed. Addition of CaF_2 reduced the total additive requirement to one-half; the smaller its grain size, the more effective was the action.—K.E.J.

Investigations of the heterogeneity of S.G. iron N. M. Zarubin (*Lit. Proizv.*, 1959, **9**, (2), 40–41) The article presents the data obtained from experiments carried out on ferritic and pearlitic irons, respectively of compositions, 2·9–3·3%C, 2·2–2·26%Si; not more than 0·4%Mn, 0·035%S, 0·02%P, and 0·05%Cr; and 2·9–3·3%C, 1·8–2·1%Si, 0·3–0·6%Mn; not more than 0·004%S, 0·02%P, and 0·05%Cr. Quantitative determination of the degree of dispersion of graphite in the powder precipitated from the cast irons by anodic deposition, and in the surface of micrographs, and qualitative analysis of graphite throughout castings and their chemical heterogeneity were measured.—M.T.

Modification of cast iron with a molten iron–magnesium alloy A. Ryzhikov and S. I. Ryabukhov (*Lit. Proizv.*, 1959, (1), 9–10) A description is given of experiments with the modification of cast iron with Mg *in vacuo*, and the development of a pressure-tight ladle for this purpose. The design of this ladle for operational use is illustrated and described in detail. One-third of the melt is treated, and after the completion of treatment is poured back into the furnace. Pouring of the moulds takes place direct from the furnace.—M.T.

A high-melting-point alloy for modification of cast iron with magnesium P. L. Stepin (*Lit. Proizv.*, 1959, (1), 10–11) It is suggested that an alloy should be prepared in an electric or crucible furnace by the introduction in the following order of: Mg (12%), Cu or Ni (12%), and 66%Fe–Si. After fusion of the charge, 15%Fe is added. This yields an alloy containing Mg 11%, Si 35%, Cu (or Ni) 11%, and Fe 43% with an m.p. of about 1350°C, which may be added to a melt of unmodified iron at 1500–1550°C. In practice, pieces of the alloy have been placed in the bottom of a ladle and hot metal poured in from the furnace. It is claimed for the method that Mg is more readily taken up by the iron, heat losses are reduced, there is less tendency to superheating, and the modification process is more stable, producing melts of better consistency. Capital expenditure on expensive, heavy, and complicated equipment is avoided.—M.T.

The use of exothermic mixes in the production of spheroidal graphite iron castings N. I. Klochnev and A. M. Sukharev (*Lit. Proizv.*, 1959, (1), 11–12) A description is given of experiments to produce an exothermic mixture suitable for use with SG iron. Since thermite has too high a reaction temperature, filter and binder components such as quartzite sand and waterglass were added, as well as KNO_3 and Al powder. At casting temperatures of 1200–1300°C the mixtures recommended create an increase in temperature to 1400–1600°C: feeding of the castings were obtained with improved microstructure. Yearly production also increased.—M.T.

Copper in cast iron: principal considerations A. de Sy (*Mod. Castings*, 1959, **35**, June, 321–328) The action of Cu in cast iron as a graphitizer and its comparatively low cost as an alloy addition are pointed out, and a discussion is given of its mode of action in the light of published results.

Alloy and technique control structure of ductile iron (*Steel*, 1959, **145**, Sept. 28, 137) Use of a high-magnesium (30–32%Mg) alloy with 4–5%Ca on a Si base is described and various advantages are claimed.

Neutralization of chromium in malleable cast iron M. A. Krishtal (*Lit. Proizv.*, 1959, (7), 34–35) To remove the influence of Cr on graphitization it may be alloyed with Sb, Se, and Te with which it forms stable compounds. In practice only Sb is used to neutralize this influence of Cr. Experimental findings transferred to a graph show that with Sb addition the diffusion coefficient of carbon increases practically linearly. The rate of graphitization in relation to the Sb content is a curve with a maximum.

Mottling in heavy section white iron castings C. R. Loper, jun. and R. W. Heine (*Mod. Castings*, 1959, **35**, June, 380–384) This is the first progress report on an investigation sponsored by AFS Malleable Div. with the object of producing heavy section castings free from mottling. The effects of C, Si, Bi, and water vapour on mottling are examined (17 refs).

The cast-iron 'family' of metals W. W. Braidwood (*Found. Trade J.*, 1959, **106**, May, Special No., 47–51) The properties of cast irons are described with special reference to spheroidal graphite, malleable, and special irons such as Ni-hard. Advances in melting and foundry techniques are briefly mentioned.

Heat-resisting chromium cast irons (*Bradley's Mag.*, 1959, Summer, 3–4) The properties of high and low-Cr irons are given.

Bismuth addition to some grey cast irons T. C. Margerie and M. Drouzy (*Rev. Mét.*, 1959, **56**, June, 47–73) Bi from 0·007–0·2% was added in the ladle to pure Fe–C–Si alloys and to commercial types of cast iron; the structure and properties of the irons obtained are examined, and the mechanism of the action of Bi is discussed (17 refs).

Ductile iron production in the basic direct-arc furnace C. R. Isleib (*Mod. Castings*, 1959, **35**, June, 341–346) Advantages of the use of the basic arc furnace for this purpose are—alloy economy, sulphur removal with low residual Mg, and reduced dross.

Foundry steelmaking T. A. Cosh (*Found. Trade J.*, 1959, **106**, May, Special No., 18–20) The high cost of coke has led to the replacement of the cupola-converter by the electric arc process. Present economics and new electric furnace techniques are discussed.—A.G.

Moulding with chamotte plastic material J. Glogier (*Prz. Odlew.*, 1957, (12), 347–354) The utilization of chamotte material for steel castings is discussed, and the technique of mould and core preparation is described. Typical defects of steel castings prepared in chamotte material moulds are mentioned. The lack of suitable moulding materials with high refractory properties has led to the use of chamotte moulding mixtures in Poland, though their use is more difficult and laborious than that of sand mixtures. They do, however, produce fewer surface defects, less porosity and fewer inclusions of moulding material. The good quality of the casting is due to the greater refractoriness and impact strength of chamotte materials, and their ability to withstand the dynamic force of the molten steel.—M.T.

The production of large castings from 13%Cr steel F. Mařan (*Slévárenství*, 1959, **7**, (5), 175–179) Some undesirable properties of the steel, encountered in using it in the construction of turbine wheels for hydroelectric power stations are discussed. On the whole the steel is very suitable for this purpose, but research on the improvement of some of its properties needs to be continued.—P.F.

Planning and production equipment in a steel foundry H. T. Nielsen (*Gjuteriet*, 1959, **49**, (6–7), 161–162, 165–166, 169–172) The modernizing and mechanization of a large Danish jobbing steel foundry are described.

Steel casting by pressing N. N. Rubtsov, G. Ya. Savkin, G. F. Balandin, and Yu. A. Stepanov (*Lit. Proizv.*, 1959, (7), 17–18) An experimental machine is described for casting steel panels 800×900 mm and 4–5 mm thick based on an idea previously described of two dies inclined to one another, one of which can be drawn towards the other, thus raising the level of the liquid metal. This action can be controlled by changing the angle of inclination of the originally open die and that of the fixed die with the horizontal. The flow of the liquid metal can be regulated from 0·5 to 2·0 m/sec.

Steel casting of a pump for refineries at the 'Strungul' works at Stalin City C. Wanyorek (*Metalurg. Constr. Masini*, 1959, **11**, (5), 433–435) A description of the casting operation of a steel pump 1200×800×750 mm weighing 800 kg.

Cast low alloy steels: Ductility and toughness J. Zotos (*Mod. Castings*, 1959, **36**, Nov., 698–704) Using a special basic electric melting practice the effect of reduction in P and S contents of cast plain carbon and Ni–Cr–Mo steels was determined. In general a significant increase in ductility and toughness occurred without loss in strength.—A.D.H.

A new method of casting steel shells with flanges J. Pribyl (*Prz. Odlew.*, 1959, (6), 165–168) In an introduction the author points out the difficulties and expense of the standard method of casting shells with flanges. To deal with the problem of runners a chill is introduced in the core and the runners on the flanges are replaced by concealed runners giving less porosity at the join of flange and main casting. Further more chills were introduced at the flange. Casting metal in moulds was not a success.

Proposed State standard for 'Casting of carbon steels in fusible patterns' S. A. Kazennov (*Lit. Proizv.*, 1959, (5), 2–5) The specification of the new GOST standard is given to replace 977–53 and part of group V82.

Applications of stainless castings for nuclear power equipment (*Ind. Heat.*, 1959, **26**, May, 968, 972) Examples of the use of stainless castings in high pressure high temperature nuclear power plants are quoted.—D.L.C.P.

High strength steel castings K. B. Holmes, J. Zotos, and P. J. Ahearn (*Mod. Castings*, 1959, **36**, July, 65–70) Mechanical properties were measured and are tabulated for steels made under various melting, pouring, and heat treatment conditions. Heats of low S and P electric arc steels gave the best combination of properties when cast in thin sections (11 refs).

The development of green sand moulding in the Lenin Works in Pilsen V. Koutecký (*Slévárenství*, 1959, **7**, (5), 179–181) The development work on bentonite type synthetic moulding mixtures and on their applications in the Škoda Works, since their early introduction in 1932, is discussed.—P.F.

Control of the moulding properties of clay-bonded sand by means of the green strength and shatter tests W. B. Parkes (*BCIRA J. Res. Dev.*, 1959, **7**, Aug., 736–744) This report shows that two entirely independent parameters, green strength, and green deformation, influence the stripping of a mould from a pattern, and that no single test can give the information required. Direct measurement of deformation is difficult, but the necessary control can be maintained by keeping green strength and shatter index within the appropriate limits.

Olivine as a moulding sand aggregate G. S. Schaller (*Machinery*, 1959, **95**, Aug. 19, 271–274) The properties and foundry uses of olivine sand are reviewed. Use as ladle linings is included.

The significance of liquid limit in evaluating bentonites for foundry use J. M. Navarro and H. F. Taylor (*Brit. Found.*, 1959, **52**, Aug., 342–355) The test, originally used for soil, in which the flow of a paste under shock is observed, is extended to bentonites for foundry use and the values found are correlated with other tests. Practical foundry trials have been made but are not described here; they are said to confirm the usefulness of the test.

Peat bitumen in moulding compounds for precision casting V. E. Rakovskii, K. M. Tkachenko, Kh. I. Rivkina, and R. M. Senina (*Lit. Proizv.*, 1959, (7), 35–37) Tests were carried out with paraffin-bitumen mixtures in which stearine was replaced by peat bitumen. Benzene is recommended as solvent since the type of solvent influences the yield of bitumen. Extensive tests have given satisfactory results which are tabulated.

Patternmaking progress W. D. Hartley (*Found. Trade J.*, 1959, **106**, May, Special No., 25–28) Advances mentioned include epoxy resin patterns, mechanized casting with metal patterns, and pressure-cast aluminium plates.—A.G.

Pattern engineering materials J. E. Olson (*Mod. Castings*, 1959, **36**, Aug., 98–102) The possibilities of the use of a new rubber-like plastic as a pattern material are discussed, and tests which have been carried out are described.

Factors governing the size of the taper in patterns N. F. Sergeichev (*Lit. Proizv.*, 1959 (1), 8) Problems of knocking out castings are discussed and causes of the difficulties are

shown to lie in the factors governing pattern taper. The calculation of the correct taper in accordance with these factors is outlined.

Production techniques and organisation for wooden patterns at the Stankolit Works N. I. Poskacheev (*Lit. Proizv.*, 1959, **9**, (2), 28–30) In order to increase the output of patterns and, above all, of core-boxes, the organization of the pattern-making section at the Stankolit Works was reorganized. The method of jointing the corners of core-boxes was changed from tenon and wedge joints to the use of dowels and bolts; which is claimed to be more durable as well as easier and quicker to produce. Mechanization of as many operations as possible has been adopted, and the various machines are illustrated and discussed.—M.Y.

A pattern for a ship's sternframe J. B. Lawson (*Brit. Found.*, 1959, **52**, Sept., 417–419) The design of the pattern for a large cast-iron sternframe is described.—A.D.H.

Design and manufacture of wooden patterns for CO_2-hardened moulds and cores J. Krejči (*Slévárenství*, 1959, **7**, (7), 291–294) Special features of pattern making arising from the use of chemically hardenable sand mixture in mould production are discussed.—P.F.

'Araldite' epoxy resins for foundry patterns (*CIBA (ARL) Ltd., Technical Notes* (197), 1959, May, pp.8) Methods are described and illustrated.

Making epoxy coreboxes from patterns J. MacClarence (*Foundry*, 1959, **87**, June, 98–99) The production of coreboxes by the use of epoxy-resin–glass fibre laminates and transfer techniques is described.

A study of the economics of the storage of foundry patterns L. Runt (*Slévárenství*, 1959, **7**, (5), 187–191) An analysis is made of the conditions under which storage of a pattern is advisable. A method for deciding when to cease storing patterns is outlined.—P.F.

Modernization of a foundry. II. Moulding machines D. Iturrioz (*Met. y Electr.*, 1959, **23**, Aug., 69–76) A description of British and American moulding machines of varying types and capacity with directions for use. **III. Core-making shop** (Sept., 104–112) An illustrated description of various core-making machines, showing some in operation, and including an example of 400 lb half-cores in series on a belt conveyor for Diesel motors.—S.H.–S.

16% Silicon acid-resistant castings A. Charmeau (*Mét. Constr. Mec.*, 1959, **91**, June, 441–442, 445, 448–449, 451–452, 457) Composition, properties, casting techniques, and applications are described of this range of castings manufactured by Société des Forges et Ateliers du Creusot.

How to improve the quality of precision castings G. Postogna (*Fond. Ital.*, 1959, **8**, April, 135–138) The writer summarizes briefly the more recent developments in the field of investment casting. From the metallurgical point of view there is an improvement in the workability of steels melted and vacuum cast. The article also described research carried out on steels for use at low temperatures.

Welded-steel flasks prove highly successful R. P. Wolgast (*Weld. J.*, 1959, **38**, April, 360–361) Some details are illustrated and described in the semi-automatic submerged-arc welding of steel foundry flasks at the Foundry Flask and Equipment Co. of Northville, Michigan.

Ceramic mold process R. Greenwood (*Foundry*, 1959, **87**, June, 84–87) A description of the Unicast process and its application.

Examples of co-operation between the mould designer and the metallurgist in foundries J. Krčmář (*Slévárenství*, 1959, **7**, (5), 172–175) Several examples are given of the redesign of moulds arising from this co-operation. The resulting improvements and economies are discussed.—P.F.

Simplified method for calculating the dimensions of shrinkage heads for steel castings with exothermal linings M. A. Kremer (*Lit. Proizv.*, 1959, (7), 19–21) The suggestion is made that the form of the heads should be oval with a circular shape of the external contour. Formulae are given for determining the dimensions and some results are tabulated.

Semi-continuous casting of iron pipes A. D. Popov (*Lit. Proizv.*, 1959, (1), 5–8) A description is given of the semi-continuous casting plant for iron pipes at the Sinarskii Tube Works. Pipes up 50 mm in dia. and 2 m long are produced, but it is aimed to produce pipes of 100 and up to 1000 mm in dia. The thermodynamics of the process and the properties of the resultant pipes are examined. The high cooling rate of the metal in the water-cooled mould lead to the formation of a very fine structure with disperse precipitation of cementite, which readily break down after the rapid removal from the mould. This has the advantage over centrifugal casting, where the resultant cementite can only be broken down by subsequent annealing which involves greatly increased costs and overheads.—M.T.

The effect of the metal stream on the inner surface of a sand mould J. Szreniawski (*Prz. Odlew.*, 1959, **9**, (8), 233–244) This study is concerned with this effect up to the point of formation of a solid skin. Three types of destructive flow are considered: the impact stream, the turbulent stream, and the jet stream. A method is described by means of which the endurance of the mould can be studied. A definition of and expression for the endurance of a mould surface are given, as well as photographs of the effect of these phenomena. It was found that the AFS and other methods used in evaluation of mould and core sands are not satisfactory from the point of view of surface endurance. Important physico-chemical phenomena are ignored. On the basis of experiment the author draws up a code of practice which considers these phenomena.

Core practice in an Israelian foundry J. Pelleg (*Foundry*, 1959, **87**, Sept., 156, 158, 160, 162) A liquid-type urea resin is used with a clay-free sand. The mix and the baking process and core properties are described.

Comparison of temperature-time curves of CO_2 and green-sand moulds A. D. Sarkar (*Brit. Found.*, 1959, **52**, Oct., 458–460) Temperature-time curves obtained with moulds having naturally bonded sand containing 6% H_2O and CO_2 bonded sand respectively showed that the latter apparently has a higher thermal conductivity.—A.D.H.

Mechanisation and automation of core production B. Bradáč and V. Prachář (*Slévárenství*, 1959, **7**, (7), 253–257) Automatic core-blowing and core-hardening machines, mostly of recent German design, are discussed, and the pre-conditions for full automation of core-making are considered. The technical development of present-day equipment is considered to be sufficiently advanced to make fully automatic core-making entirely realisable now.

A survey of the chemical hardening process and its utilization in foundries L. Petržela (*Slévárenství*, 1959, **7**, (7), 283–285) Recent developments in the CO_2 hardening of cores, such as the use of water-free dressings of the pyrogel type, basic mixtures for highly stressed parts of moulds or cores, binders with organic additives, and others are discussed.

The use of the CO_2 process in the Vitkovice Iron and Steelworks, and its future development J. Gajdušek (*Slévárenství*, 1959, **7**, (7), 285–286) The various difficulties encountered in the introduction and operation of the CO_2 process are discussed. Development plans include expansion of the use of frame-less moulding, combination of the CO_2 process with other processes in the hardening of larger castings, investigation of the full scope of chemical hardening, studies bearing on the improvement of gating systems, and others.—P.F.

The production of carbon dioxide and the scope of its utilisation in the foundry M. Kölbl (*Slévárenství*, 1959, **7**, (7), 287) Various industrial methods of the production of CO_2 are surveyed and the economical aspects are discussed. Considerable developments in its production in Czechoslovakia are envisaged for the next few years. Transportation to large consumers will be in insulated tanks in the liquid state at pressures of about 25 atm. With small containers, such as steel bombs, the cost of transportation rises appreciably.

Mechanisation in the production of castings by the CO_2 process J. Král (*Slévárenství*, 1959, **7**, (7), 288–289) The design and performance of machines of Czechoslovak manufacture used for the preparation of chemically hardenable foundry mixtures, for the production of cores and moulds from such mixtures, and for hardening these products are described.—P.F.

Machinery for the preparation of chemically hardenable sand mixtures D. Štický (*Slévárenství*, 1959, **7**, (7), 289–290) Storing and mixing of sands in the preparation of cores and moulds by the CO_2 process are discussed. The question whether dry or wet methods of sand recovery are best is still under investigation; both methods are at present in use in Czechoslovakia.—P.F.

Equipment used for hardening mixtures by the CO_2-process in the Klement Gottwald Steelworks in Ostrava J. Valášek (*Slévárenství*, 1959, **7**, (7), 290–291) The distribution of CO_2 in core and mould hardening shops is shown to be most efficient if the gas is piped from a central source, rather than from individual cylinders. In the latter case freezing up of valves and other effects lead to difficulties and wastage of gas. The method in actual use at the KG Foundry is illustrated.—P.F.

Some examples of the production of castings by the CO_2-method and, of the adaption of pattern-making techniques J. Palička and J. Polášek (*Slévárenství*, 1959, **7**, (7), 294–295).

The production of steel castings in CO_2-hardened moulds in the Ždar Steelworks M. Korejčík (*Slévárenství*, 1959, **7**, (7), 295–296) Production technology is discussed and illustrated by a specific example. Economic aspects of the process are analyzed, and are shown to justify the use of the CO_2 process for such castings, e.g. for frameworks of excavators.—P.F.

Production of steel castings in CO_2-hardened moulds in the Klement Gottwald Steelworks in Ostrava Z. Kosňovský (*Slévárenství*, 1959, **7**, (7), 297–299) The rapidly hardened moulds made by the CO_2 method are inferior to similar ones gradually hardened by the CO_2 in the air if the moulds are intended for use with complex precision castings. Details are given of the compositions and preparation of chemically hardenable mould mixtures in use at the works.—P.F.

The technology of production of CO_2-hardened cores for cast-iron castings in the CKD Works in Prague V. Vondrák (*Slévárenství*, 1959, **7**, (7), 299–300) The production methods refer to cores used in castings weighing from 200 lb to 3 t.—P.F.

The use of CO_2-hardened sand mixtures in the grey cast-iron foundries of Czechoslovak Diesel Engine works O. Novotný, P. Tropp, and K. Čipa (*Slévárenství*, 1959, **7**, (7), 300–301).—P.F.

The technology and application of CO_2-hardened core mixtures in the Šmeral Works, Brno L. Rotter (*Slévárenství*, 1959, **7**, (7), 302–304).—P.F.

Casting of automobile wheel forks into batteries of CO_2-hardened moulds J. Rous and B. Žák (*Slévárenství*, 1959, **7**, (7), 304–305) The technology as introduced in the author's works is discussed. Compared with older methods of production a 40% increase in productivity has been attained by the new process.—P.F.

The use of the CO_2 method in the production of cores B. Hodaň (*Slévárenství*, 1959, **7**, (7), 306–307) The technology developed for the production of cores in casting fittings, and for making runner funnels for use in casting steel is described.—P.F.

Assessing the CO_2 process as used in the production of grey cast-iron castings M. Stárek (*Slévárenství*, 1959, **7**, (7), 307–308) Economic aspects of the use of the CO_2 process in the Trinec Tractor Works are considered. In the series production of gear-boxes the method was found to be economically advantageous in core making but not in mould making. With smaller, hand made moulds the use of quick-drying sands may however be advantageous, particularly as the drying periods may be considerably reduced.—P.F.

Economic evaluation of the use of CO_2-hardened mixtures in the production of steel castings in the Vitkovice Steelworks M. Straka (*Slévárenství*, 1959, **7**, (7), 308) Detailed cost accounting shows the CO_2-process to be superior to the usual methods, particularly because of increased productivity. If the problem of sand regeneration could be solved satisfactorily further savings would accrue.—P.F.

Casting in metal moulds. II D. Iturrioz (*Met. y Elect.*, 1959, **23**, Nov., 81–86) The setting and

finishing of castings, the plastering and control of moulds, and the finish of surfaces of castings are described, with diagrams and examples of finishes from AIAUS with a descriptive AIA table.—S.H.S.

Some practical considerations in moulding an 18-ton housing bed in green sand H. Haynes (*Brit. Found.*, 1959, **52,** Sept., 409–412) The moulding procedure for a casting 30 ft long and 4 ft wide at the top and 2 ft deep with six T-head cores each 5 ft long and 23 in. deep is described.—A.D.H.

Centrifugal casting of cast iron waste pipes L. Jablonský (*Slévárenství*, 1959, **7,** (5), 182–184) The possibility of producing centrifugally cast pipes without the use of sand inserts is discussed, and results are given of researches on factors influencing the structure of thin-walled grey cast-iron castings made in moulds.—P.F.

Life of steel moulds for centrifugal casting H. Bühler (*Stahl Eisen*, 1959, **79,** Nov. 12, 1722–1730) Long-time studies on mould life for centrifugal casting were made using moulds of 1·8–2·7%Cr and 0·3–0·6%Mo steel. It was found that the notch-impact toughness of the steel has the greatest effect on mould life, the next is casting rate, i.e. the number of pipes cast per hour. Cold-working of the mould surface, such as peening or burnishing, may increase the life by 20–25%. The tensile strength of the steel has only a minor effect on life, but it was found that steel of higher strength showed more cracking of the surface than moulds made of lower-strength steel.

Studies on the life of steel moulds for centrifugal casting A. Koniger and W. Liebmann (*Stahl Eisen*, 1959, **79,** Nov. 12, 1730–1742) The experiments and the equipment used are described in detail. The temperatures measured during casting—particularly after repeated use—and the tensile and compression stresses observed are reported. Tensile strength of the steel does not seem to have any significant effect on the life of the mould, but it was obvious that notch-impact toughness has. Mo as alloying element has the greatest effect of all the elements studied on thermal-shock resistance.—T.G.

The effect of metal spray forming during centrifugal casting on casting quality K. U. Tsvetnenko and N. V. Rulla (*Stal'*, 1959, (11), 1034–1039) In centrifugal casting there is a critical velocity below which some of the metal breaks up into droplets. Non-uniform compositions and structures result which rolling does not rectify. The kinds of defects produced and the casting conditions producing them are considered.

Designing for shell mouldings N. Walker (*Eng. Mat. Design*, 1959, **2,** Aug.,-Sept. 432–434) A discussion of the process, the steels and other alloys used, and the precision obtainable. A brief bibliography is added.

Investment casting as compared with other foundry processes L. N. Hocking (*Brit. Found.*, 1959, **52,** Sept., 395–400) Characteristics of investment processes are compared with die casting, sand, and plaster moulding, the CO_2 process, and shell moulding. Developments in investment processes and methods are described.—A.D.H.

Solidification of grey cast iron H. Morrogh and W. Oldfield (*Iron Steel*, 1959, **32,** Sept., 431–434) The mechanization of the solidification of hypoeutectoid grey cast iron is discussed, the process of nucleation and growth being illustrated by micrographs and models.

Solidification mechanisms of eutectic and grey iron A. de Sy (*Mod. Castings*, 1959, **36,** Aug., 76–82) A study of the mechanism of grey iron solidification will be carried out during the next two years by the Belgian Centre for Foundry Studies and Research. This paper discusses solidification mechanisms under the headings of homogeneous and heterogeneous nucleation, and eutectic solidification and the resultant structures, followed by a discussion of the eutectic solidification of grey iron (10 refs).

Solidification times of simple shaped castings in sand moulds J. Bems, V. Kondic, and G. Martin (*Mod. Castings*, 1959, **36,** Aug., 39–66) Part I reviews the literature, and describes a preliminary experimental study of interface temperature. The results are discussed in relation to assumptions made in previously published work in the mathematical treatments of solidification rate when applied to sand cast shapes. In Part II, experimental work to investigate the effect of size and shape on solidification time is described, plates, cylinders, and spheres being cast in two eutectic alloys, silumin and cast iron, using different moulding materials. Mould material effects are examined in Part III. The effect of heat losses through the gating system in the derived expressions is discussed briefly (76 refs).

Interaction between the processes of solidification and crystallisation N. G. Girshovich (*Lit. Proizv.*, 1959, (7), 31–34) An analysis of the solidification process due to loss of heat and the accompanying crystallization process is given. The kinetics of both processes have been analysed in great detail but no definite relation between them has been shown. This is an attempt at a mathematical analysis by idealizing certain cases, and some conclusions have been arrived at.

Surface shrinkage defects in light sectioned grey iron castings A. G. Fuller (*Brit. Found.*, 1959, **52,** Sept., 400–409) Factors which increase surface shrinkage increase either the degree of eutectic nucleation or the heat content of the iron. The influence of iron composition, mould design, and casting temperature on these factors is reviewed.—A.D.H.

Plastic deformation during mechanical disturbance during the shrinkage of metals Ya. A. Smolyanitskii and N. I. Kaplii (*Chern. Metallurg.*, 1959, (2), 111–116) Mechanical disturbance of shrinking by cavities, protruding parts of the mould, etc. retard the beginning of linear shrinkage owing to the elastic-plastic deformation which occurs during this period. The plastic deformation in absolute units equals the free shrinkage during the temperature interval. The plastic deformation because of mechanical disturbance of the process, takes place in two stages; its development and its damping.

Pinhole occurrence in malleable castings D. R. Jones and R. E. Grim (*Mod. Castings*, 1959, **36,** July, 47–50). Experiments are described to show that pinholes in malleable castings are often caused by evolution of water vapour from some clay bonds in green sand moulds. The results are supported by published theories of the formation of pinholes in steel castings, and by the results of foundry tests.

The mutual interdependence of quality and design of castings J. Přibyl (*Slévárenství*, 1959, **7,** (6), 215–219) A systematic survey is made of the sources of faults in castings, consideration being given to the design of castings, moulds, and cores, and to the properties of foundry materials, as well as to casting technology.

Gases in cast iron L. W. L. Smith (*Bull. BCIRA*, 1959, **14,** July, 841–851) Sampling and analyses, contents, and effects of H_2, O_2, and N_2 are reviewed (29 refs.)

Design can influence foundry cooling H. E. Knowles (*Foundry*, 1959, **87,** Aug., 57–59) The problem of cooling an Arizona foundry has been overcome by open wall construction coupled with a louvred saw-tooth roof. This solution is of limited application, since a steady prevailing wind and mild winters are essential.—A.G.

Ventilation and air-conditioning in foundries (*Zváranie*, 1959, **8,** (8), 239–245) Principles and calculations on which ventilation and air-conditioning plant capacity and location are based are considered.—P.F.

VACUUM METALLURGY

Improvement of the vacuum furnace type OKB–704 for tempering steel in a magnetic field M. N. Solov'ev and I. Z. Naumov (*Promyshlennaya Energetika*, 1959, (6), 20–23) Diagrams and calculations are given on which the suggested improvements are based.

Vacuum melted metals and alloys: why use them? J. L. Everhart (*Mat. Design Eng.*, 1959, **50,** Aug., 89–97) Methods are discussed and the effects of vacuum melting, the kinds of iron and non-ferrous alloys suitable for this process and their physical and mechanical properties after melting are tabulated. A list of producers in the US is added.

Vacuum-melting at the works of Jessop-Saville Ltd (*Found. Trade J.*, 1959, **107,** Sept. 17, 179–182) The Wild-Barfield and Heraeus vacuum melting installations are described.

Vacuum melting and degassing J. Suiter (*J. Australian Inst. Met.*, 1959, **4,** Aug., 95–102) A review of the effects of H_2, O_2, and N_2 in steel and of their removal by vacuum methods. Some statistics are added.

Thicker coatings add new dimension to markets for vacuum metallizers (*Steel*, 1959, **144,** June 1, 96–97) The deposition of up to 0·004 in. of Al or Ce on a variety of metals is said to be achieved by a new vacuum metallizing process. The advantages and possible applications of such coatings are discussed.

Regarding the degassing of electro-technical steel *in vacuo* P. Ya. Sorokin, K. M. Petrov, and A. I. Kokin (*Trudy Instit. Metallurgii*, 1958, (2), 67–72) The experimental findings show that subjecting transformer steels in the laboratory to a considerable vacuum (98%) has given satisfactory results as regards wattage losses and bending tests. Casting into moulds in a low vacuum (up to 425 mm) has also given good results, especially as regards mechanical properties; 4·65 bendings against 1·75 for the normal metal. The favourable influence of the vacuum is due to the refinement of the structure. Steel produced *in vacuo* has an equiaxial fine grain structure while the normal steel has a complex crystal make-up. The H_2 content in vacuum steel decreased by 25–40% and the non-metallic inclusions by 25–30%.

Laboratory apparatus for the melting and casting under vacuum of pure iron and iron alloys M. Olette and A. Chaillon (*Publ. IRSID*, 1959, Series A (215), March, pp.11; from *Le Vide*, 1958, July–Aug., 177–187) The equipment used is described; it consists of a crucible heated by hf induction, and held under a vacuum of $\sim 10^{-5}$ mm. After melting, the metal or alloy can be run out into a Cu mould in the evacuated chamber. The composition and properties of the resulting material are described (16 refs).

Vacuum casting of steel. I M. Yoshida (*Denki-Seiko*, 1959, **30,** March, 209–222) A review, covering equipment made by Bochumer Verein, Dortmund Hörder Hüttenunion, F. T. Stokes Corp., and EFCO Edwards.

The die casting of steel under vacuum V. M. Belov and S. A. Kazennov (*Rev. Met. Mold.*, 1959, **17,** Sept., 58, 76, 78–80; from *Liteinoe Proizvodstvo*).

Decarburization of ferrochrome *in vacuo* H. Zak and B. Paczuta (*Prace Inst. Hutn.*, 1959, (2), 75–82) As introduction, the use of low carbon Fe–Cr in the steel industry is discussed followed by theoretical considerations of the mechanism of the reaction of its decarburization under normal and low pressures. The apparatus and method of work in ascertaining optimum decarburizing conditions are given. Finally the effect of the composition of the mixture; its texture, temperature, pressure and length of heat treatment, on the lowering of the carbon contents of Fe–Cr is considered.

REHEATING FURNACES AND SOAKING PITS

The use of models in the study of gas flow in soaking pits S. Černoch and I. Repisky (*Hutník*, 1959, **9,** (7), 224–227) Modifications made to the disposition and number of burners in conventional soaking pits were found to lead to more uniform performance and economies in fuel consumption. By means of the study of the flow of water in transparent models of soaking pits it was possible to clarify the nature of the improvements arising from the modifications, and to make further improvements in design.—P.F.

Heating cold ingots Z. Volf (*Hutník*, 1959, **9,** (7), 234–238) The determination of heating schedules to prevent ingot cracking by thermal stresses is discussed.—P.F.

Higher efficiency in recuperative soaking pits fired at the floor centre N. Yu. Taits, Yu. I. Rozengart, E. M. Gol'dfarb, B. L. Poletaev, I. C. Reshetnyak, and A. A. Sorokin (*Stal'*, 1959, (11), 1023–1028) At Dzerzhinsk the pits in the rail shop have ceramic recuperators which gradually develop leaks. Replacement of

the fans by steam injectors sucking air into the recuperators greatly diminished air losses. The necessary calculations for injector capacity are given. Replacement of the ceramic by metal recuperators is advised.

Radiation recuperators on oil-fired soaking pits J. F. Whitfield (*Iron Coal Trades Rev.*, 1959, **179**, Aug. 14, 27–30) A description of the pits used at Round Oak, their operation, recuperator design, and performance, with data of temperatures and air flows is given.

HEAT-TREATMENT AND HEAT-TREATMENT FURNACES

Introduction to the heat treatment of steel P. J. Kool and J. van der Linde (*Metalen*, 1959, **14**, Sept. 30, 276–279; Oct. 15, 294–297; Oct. 31, 314–319) After a lengthy discussion of the physical phenomena connected with the production of iron and steel alloys, the paper goes on to deal with the effects exerted by the various recognized heat treatment processes such as annealing, hardening, tempering, quenching, carburization, and nitriding, with reference also to the various ways in which they may be carried out together with the properties obtainable. Numerous diagrams and photomicrographs appear in the text.

Modern heat-treatment equipment L. G. W. Palethorpe (*Wild-Barfield Heat-Treatment J.*, 1959, **7**, June, 2–7) A lecture. Atmosphere plants, jigs, quenching, and induction heating equipment are reviewed.

Heat treatment of roll sleeves for large cold-rolling rolls F. Holoubek and J. Otáhal (*Hutn. Listy*, 1959, **14**, (5), 415–421) Details of the production technology used with 3½ ft diameter Cr–V acid steel sleeves are given.—P.F.

Heat-treatment control cuts reject rate N. B. MacLaren (*Metalw. Prod.*, 1959, **103**, June 12, 1032–1033) A code book of steel grades and treatment has been compiled.

Determination and control of the optimum fuel–air ratio based on maximum temperature A. L. Malyi (*Metallurg.*, 1959, (5), 34–38) The possibility is examined of using a method based on a new principle, i.e. of controlling combustion by an automatic or manual search for such air consumption as ensures the maximum temperature of the flame. Experiments at various metallurgical works are quoted and a scheme of automatic control is suggested for which appreciable advantages are claimed.

The gradient furnace—a versatile research tool A. Feduska and P. E. Busby (*Met. Progress*, 1959, **75**, June, 92–96) Gradient furnaces can be used to obtain rapidly heat treatment data on experimental steels, and for the solution of specific heat treatment problems where temperature is an important variable. An example of such a furnace is described, and some results are discussed.

Malleable and pearlitic irons heat treated automatically (*Steel*, 1959, **145**, July 6, 92–94) A brief outline of the arrangement at the Marion Malleable Iron Works, Indiana.

Enlarged research and development facilities of The Electric Furnace Co. (*Ind. Heat.*, 1959, **26**, June, 1124–1138) The extensive furnace and other plant for investigating and developing heat treatment technique are described.

Controlled atmosphere generation J. McMullen (*Metalw. Prodn.*, 1959, **103**, Aug. 21, 1275–1277) The production of reducing atmospheres with dew-point meter control for closed-quench furnaces is reviewed.

Overcoming the producibility barrier by better use of atmospheres in heat treating and metal processing (*Met. Prog.*, 1959, **76**, Oct., 146–157) **I. Trends in atmospheres** (146–150) Types of atmospheres and generators, vacuum as an atmosphere, and the use of by-product N_2 and other developments are reviewed. **II. What's new in atmosphere controls** (150–153) Safety controls, continuous generator control and various types of control panel are described. **III. Choosing the right atmosphere** L. L. Patton (154–157) Types of atmosphere and their applications are discussed. **Atmospheres in missile heat treatment** N. K. Koebel (156–157) Problems and techniques applied are reviewed.

Influence of prior heat treatment of steel on the kinetics of the transformation of supercooled austenite V. G. Gorbach and V. D. Sadovskii (*Trudy Inst. Fiz. Met.*, 1958, (20), 311–326) The possibility of restoring the austenitic grains corresponding to the original state by very slow or by very rapid heating of the quenched steel has been proved. The rate of heating at which restoration of the original grains of the quenched untempered steel is observed is reduced with an increased Cr content. This confirms the hypothesis that the restoration of the grain in this case is related to the possibility of austenite formation without diffusion.

Effect of alloy elements on the persistence of martensite when tempering at low heat B. A. Apaev, S. N. Krasotskaya, and B. Yakovlev (*Chern. Metallurg.*, 1959, (4), 89–92) On the basis of experimental findings it may be said that the alloy elements have an appreciable effect on the rate of the first stage of martensite decay. Their individual influence is observed very clearly when tempering at low heat (100°) so that according to their respective effects on the strength of the martensite they may be classified in the order: Mo, V, W, Si, Mn, Cr, Ni.

Hardening and tempering structure of mild steels S. Modin (*Jernkonts. Ann.*, 1959, **143**, (6), 335–369) Two C steels containing 0·09 and 0·18%C, and one with 0·19%C and 1·16%Mn were fully hardened and tempered to 200–700°C, and structures examined before and after tempering. Incompletely hardened specimens were also investigated. Metallographic examination was carried out with the optical and electron microscopes, and mechanical tests were made. The structures obtained are discussed in detail (14 refs).

Structure mechanism of phase recrystallisation when heating steel V. D. Sadovskii (*Trudy Inst. Fiz. Met.*, 1958, (20), 303–310) The process of phase recrystallization consists of two stages, the phase transformation proper, resulting in the formation of the original austenitic structure, work hardened, and oriented, and the recrystallization of the austenite resulting in the removal of the work hardening and the elimination of intragranular structure. The article treats in detail these basic assumptions.

Strengthening the metastable austenite alloys by means of phase hardening K. A. Malyshev, N. A. Borodina, and V. A. Mirmel'shtein (*Trudy Inst. Fiz. Met.*, 1958, (20), 339–348) In the presence in austenitic alloys and steels of the direct and reverse martensite transformation $\alpha \leftrightarrows \gamma$ it is possible to increase the strength of the austenite by a small factor by means of heat treatment without external work hardening. Since, as a result of phase-hardening, the austenite appearing in the direct and reverse martensite transformation is stabilized, not only its strength but also its resistance is increased. Maximum strength is obtained by a single cycle of direct and reverse martensite transformation; repeated transformations result in only a slight increase in the yield point.

Curing tool hardening troubles C. D. Doescher (*Metalw. Prod.*, 1959, **103**, Oct. 9, 1614–1616) Heat-treatment is discussed and examples of hardening procedures are given on a question-and-answer basis.

Oxy-town gas flame hardening (*Engineer*, 1959, **108**, Sept. 11, 232–233) An illustrated account of the Peddinghaus system.

How Germany uses flame hardening W. A. Hawkins (*Metalw. Prodn.*, 1959, **103**, Aug. 28, 1311–1318; Sept. 25, 1507–1510) Peddinghaus oxy-town gas equipment is reviewed. Gear hardening is then described.

Furnace design promotes uniform carburizing quality H. F. Coyle and M. E. Lackey (*Iron Age*, 1959, **183**, May 21, 148–151) The design of carburizing furnaces is discussed stressing the need for good heat distribution and a proper temperature control system. A description is given of a new horizontal type furnace with protected quench.—A.G.

Magnetometric investigation of electrical tempering of steel V. N. Gridnev, V. G. Permyakov, and V. T. Cherepin (*Metallov. Obra. Met.*, 1958, (4), 9–16) This study carried out on tool steels shows that at rates of heating up to 10 000°C/sec. martensite decay and carbide reactions proceed according to the pattern observable during slow heating. The residual austenite decomposition is, however, suppressed. If the temperature rises above the beginning of the third transformation (over 400°) the residual austenite decomposes into a ferrite–carbide mixture. The loss of stability of the residual austenite is obviously due to the considerable volume effect of the third transformation. With the third transformation, low temperature carbide changes into an intermediate form and this is accompanied by volume, magnetization, and specific heat changes. With increased temperatures cementite forms, resulting in further magnetization changes.

FORGING, STAMPING, DRAWING, AND PRESSING

Precision upsetting of stampings and drop forgings R. Meier (*Werkstattstechn.*, 1959, **49**, Jan., 35–38) The author describes an upsetting process in which stampings and drop forgings are cold worked to required thicknesses within very small tolerances. The quality of the surface is similar to that of finish machining. A number of practical recommendations are given.—T.G.

Characteristics of steels F. J. M. Gallego (*Met. y Electr.*, 1959, **23**, Sept., 115–118) The characteristics of rolled and forged steels, including large forgings for Diesel motors, their treatment, and resultant mechanical properties are described.–S.H.–S.

Cold finished steel cuts cost of precision parts L. U. Davis (*Mat. Design Eng.*, 1959, **50**, Sept., 108–110) Selection for machining, hardening, cold forging, and for welding is tabulated and tolerances, mechanical properties, and applications are briefly discussed.

New techniques broaden forging picture.—I J. H. Jackson and H. B. Goodwin (*Met. Progress*, 1959, **76**, Aug., 97–102) The following techniques are discussed—the counterblow hammer, the 'impactor', the precision forging process, the 'continuous grain flow' process, and roll forging.

Bigger, better and sounder forgings E. E. Thum (*Met. Progress*, 1959, **76**, Aug., 103–108) The metallurgical work carried out to remove the limitation imposed on forgings for large electrical generators by increased size and stress requirements is outlined.

Investigation of the stress state of the metal under deformation in forging and rolling I. Ya. Tarnovskii, A. A. Pozdeev, V. P. Kotel'nikov, and S. G. Puchkov (*Chern. Metallurg.*, 1959, (3), 37–45) A simple method is proposed for investigating the stress state in metals subjected to pressure treatment and has been confirmed experimentally. The longitudinal tensile stresses in forging and rolling appear within calculable dimensional relations from the focus of deformation. The main factor for determining the longitudinal tensile stresses is the ratio between the length of the deformation focus and the average thickness of the strip H_c. Tensile stresses are given for various values of the ratio l/H_c.

Producing blanks for multiple-diameter shafts by the cold-forming method H. C. Seifert (*Machinery*, 1959, **95**, July 22, 99–103) A description of the process, the dies and tools used, and the blanks and finished products is given.

Contribution to the present state of knowledge in cold and hot shaping processes O. Kienzle (*Microtecnic*, 1959, **13**, April, 61–65) An account of work on deformation processes including a large section on surface roughness. Shaping processes are tabulated and drop-forging shapes are illustrated. Work hardening, precision, and measurement are all taken into account.

Scythes, sickles and forks in fine steels (*Aciers Fins. Spéc.*, 1959, July, 62–65) Methods of production are outlined.

Examples of quality control in the forging shop T. Yoshikawa (*Denki-Seiko*, 1959, **30**, March, 171–182) [In Japanese].—K.E.J.

Metal working processes and equipment: VI A. G. Thompson (*Weld. Met. Fab.*, 1959, **27**, June, 253–256) The purpose and principles of vertical plate benders and press brakes are explained.—D.L.C.P.

Materials handling at the new Vauxhall press shop (*Mech. Handling*, 1959, **46,** July, 378–381) With illustrations and plan.

On the warm-working of medium carbon steels M. Ono (*Sumi. Met.*, 1959, **11,** April, 123–131) With warm-working (at 500–600°C and with reductions of 2–4%), the improvements in properties compared with the normalized condition are: tensile strength 73–83 from 72–74 kg/mm², elongation in 50 mm is reduced to 16–23 from 25–26%.

Hefty handler cuts die change time (*Steel*, 1959, **145,** Aug. 3, 80) A truck for conveying die assemblies to the stamping press is briefly described.

Ten uses of stainless steel wire R. J. Berkol (*Prod. Eng.*, 1959, **30,** Design Digest Issue, mid-Sept., 74–75) The processes of cold-heading, hot upsetting, warm heading, slide forming, weaving, welding, use for springs, wire rope, and metal spraying are tabulated with brief discussion. Suitable grades are indicated.

Concerning the calculation of deformation in bimetallic linings during stamping L. Yu. Pruzhanskii (*Metallov. Obra. Met.*, 1958, (5), 13–16) Expressions are derived for the distribution of stresses in stamped bimetallic cylinder linings. The stresses in steel-Al alloy and in steel-babbit linings are plotted on graphs and are below the yield point of the respective metals.

Explosive forming by pneumatic machine (*Metalw. Prod.*, 1959, **103,** June 19, 1070–1071) The Dynapak, developed by Convair is described. Energy rates up to 1500000 ft/lb are available for extrusion or forging to close tolerances and with good surface finish. Three sizes are available.

An explosive sheet material for hardening and forming metals (*Machinery*, 1959, **95,** Oct. 7, 697–698) An account of DuPont EL–506A flexible sheet PETN and its uses is briefly given.

Stretch former compensates for yield strength variations (*Iron Age*, 1959, **183,** April 23, 110–111) Contour forming of high-strength heat resistant metals must be done between the yield point and the point of ultimate failure, often only 5%. The stretch-forming machine described measures the yield strength on each workpiece and thereby cuts scrap rates.—A.G.

Grotnes expanding and shrinking machines with high-pressure lubrication (*Machinery*, 1959, **95,** Oct. 7, 689–691) A machine with a draw-bar pull of 1580 t and another for jet-engine rings with a polyamide-tube lubrication system are described.

Hydraulic roll forming bends big bumpers Redman Tools and Products Ltd (*Metalw. Prod.*, 1959, **103,** Aug. 14, 1235–1239) A large forming machine is illustrated.

Automatic line makes bars from coiled steel rods (*Steel*, 1959, **145,** July 6, 84) A machine controlled by one man is reported.

Hot forming sheet metal parts with improved forming techniques A. F. Hofstatter (*Met. Prog.*, 1959, **76,** Oct., 97–99) Ti is mainly considered but the methods described are also used for 17–7 PH stainless steel.

Application of stretch reducing of tubes for greater production and economy W. Rodder (*Iron Steel Eng.*, 1959, **36,** July, 100–106) The stretch-reducing process is described and illustrated, and tables are given showing typical reductions in existing mills, and rolling schedules for small and large tube sizes.

Oscillating equipment for drawing components V. K. Rogov and K. R. Rotov (*Stal'*, 1959, (11), 1033) An invention is briefly described in which an electromagnetic vibrator transmits power by hydraulic means to the die.

Tempering, cutting out and shaping hard alloy steel by a flexible sheet explosive R. Brocard (*Usine Nouv.*, 1959, **15,** Dec. 17, 99) The use of PETN with the addition of certain ingredients which impart flexibility, is described as applicable to a wide variety of steel shapes, especially manganese steel, without damage or deformation.—S.H.–S.

Wet wiredrawing J. K. Annandale (*Wire Ind.*, 1959, **26,** Aug., 741–746) A description of the process and the machines used.

Improved methods of producing shaped section wire for lock coil cables A. L. Tarnavskii, S. M. Fomin, O. A. Ryabshikova, and F. S. Revzina (*Stal'*, 1959, (11), 1029–1033) Z-section wire is drawn through idler rolls mounted on a wire-drawing machine.

Workshop studies on the effect of drawing temperature on the mechanical properties of steel wire F. Schwier (*Stahl Eisen*, 1959, **79,** Oct. 1, 1385–1391) As a result of increased drawing speed and the use of multi-die machines, the steel work-hardens more during wire drawing than at lower speeds in single-die machines. Consequently, as a harder wire requires a greater work of deformation in drawing than a softer one, the temperature of the wire in modern machines is very much higher. The effect of temperature, additional cooling, and of a surface pass on wires produced by six works was studied. A surface pass or a straightening operation can improve the mechanical properties in cases where cooling was not properly carried out; naturally correct cooling ensured the best properties.—T.G.

Graphical method for the determination of parameters for steel wire drawing B. Kunda (*Wire Ind.*, 1958, **25,** Dec., 1139–1142) Graphs are given for calculating such factors as drawing force, power requirements, and reduction in area. Their use is illustrated by an example.

Some aspects of steel extrusion R. Cox, T. McHugh, and F. A. Kirk (*JISI*, 1960, **194,** April, 423–434) [This issue].

Some experience in tube extrusion G. Sachs and A. Draper (*Microtecnic*, 1959, **13,** April, 66–76) Tests were carried out on a laboratory scale using Pb and Pb–Sb alloy. The findings are referred to stainless steel and other metals.

Plastic working F. W. Boulger (*Mech. Eng.*, 1959, **81,** Sept., 60–62) A literature review of rolling, cold, warm, and hot working and extrusion 1955–1958 (46 refs).

ROLLING MILL PRACTICE

Experiments on power and output requirements in the hot rolling of plate on the Lauth 3-high mill A. Geleji, E. Kiss, and G. Dévényi (*Acta Techn.*, 1959, **24,** (1–2), 157–180) Full details are given of measurements of rolling pressure and power made by the (Hungarian) Heavy Industries Technical University. The measurements are evaluated and compared with calculated results obtained by the method according to Geleji. (*Die Berechnung der Krafte und des Arbeitsbedarf bei der Formgebung in bildsamen Zustande der Metalle*, Akademischer Verlag, Budapest, 1955; *Acta Techn.*, 1957, **18,** 77–100; *Stahl Eisen*, 1957, **77,** 931–933).

Programming of a rolling service for special steels M. Cabane (*Centre Doc. Sidér. Circ. Inf. Techn.*, 1959, (5), 1137–1142) Organization is briefly discussed and suitable tables showing delegation of duties are drawn up.

Calculation of rolling forces using the Orowan theory J. E. Hockett (*ASM preprint*, 149, 1959, Nov., pp.19) The 'exact' theory is modified and electronic computation is applied. Tests on U sheet are compared with calculation and the value of the modified theory for design is shown.

Effect of outer zones on resistance to deformation when rolling in grooves M. Ya. Brovman (*Stal'*, 1959, (9), 829) Trials on lead bars are briefly described.

Sendzimir mill for stainless steel (*Sheet Met. Ind.*, 1959, **36,** Aug.–Sept., 574–576) An illustrated account of the Jones & Laughlin ZR22–50 in type rolling strip up to 50 in. wide and from 0·188 to 0·003 in. thick.

Criteria for the stress conditions of the metal during rolling in grooves M. A. Zaikov (*Chern. Metallurg.*, 1959, (3), 47–64) Equations and formulae are evolved which make it possible to calculate the complex dependence of the resistance to deformation on the deforming factors. These simplify the mathematical analysis of the process because the limiting values of the main criteria of the stress conditions derived from the force of friction are reduced to unity.

Cast iron compound rollers for sheet cold rolling B. Raczynski (*Prz. Odlew.*, 1958, **9,** (8), 250–253) A method of manufacture of rolls for cold-rolling and polishing is described, including the charge, melting, casting, and casting properties. Prospects of improvement are outlined.

Study of the deformating of work rolls on a 4-high cold rolling mill B. Fazan (*Centre Doc. Sidér. Circ.*, 1959, **16,** (5), 1143–1153) The measurement technique in this investigation is described. The following factors were studied: deformation at the contact work roll–back-up roll; forces acting on the working roll; deformation of the neutral axes of the work roll and back-up roll. It is shown that, in spite of the high degree of rigidity of the back-up rolls, the warping of the work roll in a 4-high mill can be substantial.

Investigating the forces in rolling with variable radii rolls A. P. Chekmarev, A. F. Smol'yaninov, and P. L. Klimenko (*Chern. Metallurg.*, 1959, (4), 65–72) Tests were carried out on 150 and 330 mills with wedge-like lead specimens in order to obtain the total pressure for each separate section. Special rolls and special apparatus were constructed.

Preventive maintenance in hot rolling mills O. Thelin and R. Öbring (*Jernkonts. Ann.*, 1959, **143,** (10), 683–694) Organization, including record systems and inspection are discussed, with reference to American practice (13 refs).

Evaluation of the life of cold-rolling rolls P. Funke and P. Funke jun. (*Stahl Eisen*, 1959, **79,** Oct. 1, 1412–1419) For the evaluation of the life of cold-rolling rolls a card record system has been developed in which the diameter reduction is reported which is found during regrinding. This system allows the time at which it becomes uneconomical to regrind a roll to be found, i.e. when the roll should be hardened again, to see whether the roll has been subjected to too high stresses during use and to compare the quality of rolls supplied by different manufacturers. The coefficient used for this evaluation is the number of working hours per mm grinding loss.—T.G.

Computer synthesis simplifies roll forming H. M. Lakin (*Metalw. Prod.*, 1959, **103,** Oct. 23, 1708–1709) Simulation of the roll-forming process simplifies its application to various shapes.

Rolls for sheet mills. The ultrasonic testing of rolls R. A. Villanueva (*Met. y Elect.*, 1959, **23,** Nov., 90–97) The nature and use of the ultrasonic detection of flaws in the testing of rolls is described, with a table of typical velocities of ultrasonic waves, and 12 diagrams, including eight of rolls under test.—S.H.–S.

Automatic continuous lubrication of universal mill spindles W. L. Stover (*Iron Steel Eng.*, 1959, **36,** June, 89–92) Centralized lubricating systems either direct a spray to the outside of the coupling joint, inject oil into an air stream fed to the segment faces through holes in the spindles, or feed an oil mist through such holes.

The importance of edging passes in the rolling of blooms W. Leskiewicz (*Hutnik*, 1958, **25,** (10), 386–390) Experiments were carried out on a 2-high 2800 mm reversing stand (roll dia. 1150 mm) with HL2 rimming steel ingots 1410 × 635 and 1459 × 685 mm, weighing 15 t, which were rolled without an initial edging pass and with two edging passes giving a total reduction of 50, 90, and 130 mm and the unevenness of deformation was measured after the 4, 6, 8, 10, and 12th passes, after which the unevenness of deformation was removed by two further edging passes. The unevenness of deformation was removed by two further edging passes. The unevenness of deformaton was again measured after the ensuing last five passes. It is concluded that the total reduction on the first two edging passes should be about 90–100 mm and that the width of the wide face of the ingot should be about 110 mm greater than the rolled length of the bloom and the difference should not exceed 150 mm. Rolling outside these limits leads to the appearance of faults in the blooms and wastage of metal; The limits of the first two edging passes are most important and must be strictly adhered to.

Integrated long bar processing (*Mech. Handling*, 1959, **46,** Sept., 502–504) McCalls Macalloy Ltd's installation for prestressed steel bar at Sheffield is described.

Causes of the formation of surface defects on billets and section shaped rolled products V. F. Isupov, O. A. Smirnova, and T. M. Saar (*Stal'*, 1959, (9), 842–845) A tracer study using ^{110}Ag which was introduced into holes drilled near

the defects before rolling is described. The effects produced in billets and shapes by various types of ingot surface defects are described.

Cross roll and roller straightening machines for round bars, tubes and sections H. Makelt (*Wire Ind.*, 1959, **26,** March, 273–280) Nomographs are given for calculating the power requirement of a straightening system, together with a worked example. Various design of straightening machines are described.—A.G.

Principles of the roll pass design of section steel Z. Wusatowski (*Acta Techn.*, 1959, **22,** (3–4), 361–394) [In German] General relationships are derived for processes of plastic deformation and, assuming constancy of volume, equations are obtained for calculating simple profiles of up to three parts. Experiments carried out by the author are then described which verify the accuracy of the expressions derived (11 refs).

Shaping of bars rolled on vertical mills J. Klašterka (*Hutník*, 1959, **9,** (6), 199–204) The equipment and technology of steel bar manufacture are discussed with special reference to the relative merits of horizontal and vertical mills.—P.F.

The problem of straightening bars, tubes and sections in steel and non-ferrous metals. Machines utilised for this work Tihay (*Centre Doc. Sidér. Circ.*, 1958, **15,** (11), 2317–2349) After a brief reference to manual dressing the author describes the various types of mechanical straightening equipment, and gives examples of some Continental models. The article is illustrated by a large number of diagrams.

The modern plate mill M. F. Dowding, C. Sturdy, and A. A. Thomas (*JISI*, 1960, **194,** April, 486–494) [This issue].

Flexibility designed into die shear line (*Iron Steel Eng.*, 1959, **36,** May, 155–156) The die shear line described was designed by the McKay Machine Co. of Youngstown, Ohio, to handle coiled metal in a large range of thicknesses and in any width. Automatic programming can be incorporated, and an electronic surface measurement device is included.

Automatic control for rolling mills English Electric Co. (*Sheet Met. Ind.*, 1959, **36,** June, 431–433, 436) A system based on the BISRA design is demonstrated on one-eighth scale.

Cropping mill-length bar stock Ford Motor Co. (*Auto. Eng.*, 1959, **49,** Aug., 315) An illustrated account of the 250-t press installed for laminated spring production at Dagenham.

Remote control aids rolling mill (*Iron Age*, 1959, **183,** April 23, 104–105) The mill described has been developed for rolling fissionable materials either alone or in sandwich elements. One of four different roll assemblies can be inserted in the mill to meet various requirements.—A.G.

An experimental approach to some control problems of multi-stand rolling mills H. Gill (*Trans. Soc. Instr. Techn.*, 1959, **11,** June, 97–105) A three stand model mill has been constructed in view of the difficulties of a purely theoretical approach, and experimental results are quoted and used to make it practically self-regulating in respect of ingoing gauge and outgoing tension.

Magnetic amplifier control for reversing hot mill auxiliaries R. L. Duke and L. R. Hulls (*Eng. J.*, 1959, **42,** July, 89–92) A general description of the performance requirements and a discussion of the use of magnetic amplifier regulators.

Automatic slow-down equipment for strip mill English Electric Co. (*Engineer*, 1959, **208,** Aug. 28, 153) A device for counting the turns left on reversing cold strip mill reels during coiling and uncoiling developed by English Electric is described.

Slowdown control in cold steel strip production (*Process Control Autom.*, 1959, **6,** Sept., 402–403).

X-Ray micrometry in hot-rolling at Volta Redonda P. Silva (*ABM Notic.*, 1959, **13,** Aug., 4–9) The application of X-ray micrometry to plates and other products of the hot-rolling plant is described, with a table of pressures under 14 gauges.—S.H.–S.

Possibilities of a gammascopic device for detecting cavities in blooms during rolling A. Kohn (*Centre Doc. Sidér. Circ.*, 1959, **16,** (5), 1123–1135) The principle, development, and present form of a device using ^{60}Co as a source of γ-radiation for detecting cavities in blooms during rolling are described, and examples are given showing the recording of the trace, corresponding bloom sections and the assessment of the records.

WELDING AND FLAME CUTTING

11W.–Commission IX. Recommendations for the choice and classification of steels for welded structures (*Soud. Techn. Connexes*, 1959, **13,** March–April, 99–102) Reference is made to the factors to be considered when choosing a steel for welded structures. Weldability is discussed in relation to prevention of defects in the weld area. Four types of C–Mn steels are defined on the basis of load and service conditions anticipated. Chemical analyses and impact values are recommended.—R.P.

Electro-slag welding G. Z. Voloshkevich (*Avtom. Svarka*, 1953, **6,** (6), 3–10) This is the original account of the process in which a conducting slag is used for electrical heating of the weld metal.

Welding and metallizing in repair and maintenance work on rolling stock of the Italian State Railways C. Bolognin and M. Voltolini (*Riv. Ital. Saldat.*, 1959, **9,** May–June, 103–109) This article describes the applications of welding and metallizing and cites examples which show that these two can be alternated so that in cases when welding is not practicable either for reasons of cost or weldability the metallizing process can be substituted giving better results.

Development of a transition weld between ferritic and austenitic superheater tubing for steam plant operation B. Löfblad and J. Lindh (*Soud. Techn. Connexes*, 1959, **13,** March–April, 103–111) A short review of welding methods is followed by calculations regarding shrinkage and mechanical and physical properties of austenitic as well as ferritic steels. The weld between these metals is made using a stabilized high-nickel alloy having the same Cr content as the ferritic material. Heat treatment and brittleness tests have shown that this welding method is satisfactory.—R.P.

Modern points of view in the welding and construction of boiler components W. Müller (*Schweissen Schneiden*, 1959, **11,** May, 159–171) Problems connected with the present-day use of higher temperatures and pressures are discussed, with reference to the types of steels and the welding techniques employed. Operational data are given (12 refs).

Welding with an electric arc rotating in a magnetic field N. Ya. Kochanovskii, E. S. Feder, and S. M Katler (*Svarochnoe Proizv.*, 1959, **32,** (8), 1–4) The phenomenon of rotation of the arc, hitherto observed between a central fixed cathode and an anode, is now shown to be possible where both anode and cathode rotate, and either form separate parts of the work to be welded or consist of the work and an auxiliary electrode, two coil windings in a differential circuit creating the magnetic field. In consequence, no welding heads or torches are required to pass along the weld, radically simplifying welding in confined spaces, or where access is bad, and may be applied in particular to tubes and components of heavy cross-section with flanged joints. Sources of supply of low heat output may be used. Further research is required on arcs in a magnetic field which besides rotating may also move in other senses.—M.T.

Arc welding of studs to alloy steels, cast iron and non-ferrous metals D. J. Vainboim (*Svarochnoe Proizv.*, 1959, **32,** (9), 35–37) The research conducted shows the possibilities and limitations of arc stud welding. A technique for submerged arc welding steel studs to grey cast iron with the use of a supplementary copper ring to press against the end of the stud to be welded is described.

Automatic submerged arc welding of thin sheets of different steels K. V. Lyubarskii and M. I. Sorokina (*Svarochnoe Proizv.*, 1959, **32,** (11), 3–6) On the basis of investigations of welding techniques, metallurgical assessment of various fluxes, tensile tests, and structural analysis of the weld metal and the welded joint, a technique is presented for automatic submerged arc welding of butt joints between thin sheets of an austenitic-ferritic and a pearlitic steel.—M.T.

Resistance welding of main pipelines B. E. Paton, G. V. Gorbunov, V. K. Lebedev, N. G. Ostapenko, and M. D. Litvinchuk (*Svarochnoe Proizv.*, 1959, (2), 1–5) During 1959–1965 it is planned to lay 50000 km main pipelines in Russia, of which 26000 km are to be in pipes 720–1020 mm dia. A series of experiments has been carried out to compare the assembly welding of such mains by automatic submerged arc welding, hand arc welding, and resistance welding. The greatest economy and output were obtained from the latter method which also permits full mechanization and continuous pipeline construction. Illustrations and description are given of the equipment employed and in particular of self-propelled machines.

In investigation of the technique of welding the main girders of bridge cranes of 5–50 tons capacity Tsyan Tsu-ni (*Svarochnoe Proizv.*, 1959, **32,** (10), 3–7) As a result of the technique described, the time required to fabricate the two girders of a 5-t bridge crane was reduced from 400 to 90 h, and the operation of straightening by heating with a torch was eliminated.

Arc plasma jet as a source of heat during the treatment of metals I. D. Kulagin and A. V. Nikolaev (*Svarochnoe Proizv.*, 1959, **32,** (9), 1–4) The method of formation of the plasma jet in a shield of inert gas and its thermal and mechanical props, are outlined, with descriptions of automatic and manual plasma jet heads. He+A and A were used with C and W electrodes. The range of applications is discussed.—M.T.

Plasma heating in welding processes K. V. Vasil'ev and A. A. Isachenko (*Svarochnoe Proizv.*, 1959, **32,** (9), 5–6) The results of experiments in the use of such heating for existing welding processes and its advantages are discussed.—M.T.

Energy and heat conditions during friction welding R. I. Zakson and V. D. Boznesenskii (*Svarochnoe Proizv.*, 1959, **32,** (10), 21–22) The energy required at the outset must be calculated on the basis of conditions of constant specific pressure over the cross-section of the specimen, and during the main stage on the basis of evenness of wear of the surface. Heating is uneven over the cross-section; at the outset the external layers are better heated, but later the maximum heat moves towards the centre. Finally it evens out to about 1000–1100°C for steel. Duration of the process must be determined by attainment of the maximum temperature and its equalization over the section.—M.T.

Atomic hydrogen welding in tube production Yu. V. Klyamkin, Yu. V. Manegin, A. T. Konyushenko, R. V. Golovkin, and N. N. Protopopov (*Stal'*, 1959, (9), 821–827) Alloy steels difficult to pierce can be welded with torches and techniques are described. A six-arc automatic torch was developed for the purpose.

Report upon the bonding of sheet metals and the preparation of sheathing H. Gerbeaux (*Ciencia tecn. solda.*, 1959, **9,** July–Aug., 3/322, 1–15) The relative advantages of solid and reinforced steel building construction, with the use and welding of steel and alloy-sheets, sheathing and tubing are described; 16 diagrams show in detail the preparation of edges of sheets for welding, the use of steel sheathing, with a table of metals and their appropriate electrodes.—S.H.–S.

Vertical downward welding in the manufacture of large storage tanks A. Buchholz (*Schweissen Schneiden*, 1959, **11,** July, 285–288) Comparative trials between upward and downward welding showed that the latter, although requiring experience, gave results at least as good as with upward welding, and compared favourably in cost.

Butt welding of roller bearing cage blanks S. S. Astaf'ev, D. S. L'vov, and Yu. L. Rozhdestvenskii (*Svarochnoe Proizv.*, 1959, **32,** (8), 18–21) An improved method of fabrication is outlined.—M.T.

The production line for large-diameter welded tube at the Sedan plant of the Société Lorraine–Escaut J. Petit (*Techn. Mod.*, 1959, **51,** April, 197–206) The layout, operation, and capacity of this recently enlarged plant are described in detail. Welding is automatic, using a modification of the Unionmelt process.

American Welding Society bibliographies, 1958, pp.148. **Brazing** (pp.5). **Cast iron** (pp.3). **Destructive examination in welding** (pp.14). **Electrodes and welding rods including their coverings and fluxes** (pp.8). **Inert-gas metal-arc welding** (pp.9) **Inspection and non-destructive examination** (pp.6). **Welded machinery construction** (pp.3). **Piping and tubing** (pp.7). **Resistance welding** (pp.13). **Stainless steel** (pp.7) The compilation is of references to papers appearing in the *Welding J.* since 1937 or 1940, in chronological order.

The automatic welding machine VUS-AS-4 for welding under molten slag M. Mosný (*Zvar. Sbornik*, 1959, **8,** (2), 148–193) [In Slovak] A recently developed universal automatic welding machine is described in detail, and several specific applications are discussed.—P.F.

Industrial uses of electroslag welding in the Soviet Union E. Bishop (*Weld. Met. Fabr.*, 1959, **27,** Aug.–Sept., 316–319) A review showing large welding jobs carried out with this process.

Experiments for adapting the butt-welding machine MSP.500 to the welding of rolls of tape N. M. Kolpovskii (*Stal'*, 1959, (10), 937) The joint produced is satisfactory but faults in the design of the machine are noted.

Some problems of ultrasonic welding S. B. Ainbinder (*Svarochnoe Proizv.*, 1959, **32,** (12), 4–6) An outline is given of the mechanism of ultrasonic welding and methods of setting up the required vibration in the components to be welded, indicating the distinction between this and cold-welding, namely the absence of hardening and internal stresses, so that it may be applied to metals with low plasticity.—M.T.

Development of a transition weld between ferritic and austenitic superheater tubing B. Löfblad and G. Lindh. (*Weld. Met. Fabr.*, 1959, **27,** Aug.–Sept., 325–330, 349) A high-Ni alloy with the same Cr content as the ferritic steel and with the C stabilized with Nb or a similar element is used. The properties of the metals and joints are set out and structures are shown.

Reclamation of a 30-ton steel casting G. G. Musted (*Brit. Weld. J.*, 1959, **6,** Aug., 351–353) Salvage of a cast steel drop hammer frame is described.

The use of increased electrode pressure during spot welding of low-alloy steels G. A. Maslow and B. B. Zolotarev (*Svarochnoe Proizv.*, 1959, **32,** (12), 16–18) Increased electrode pressure was found to increase spot quality, remove macro-defects, increase the strength properties of the joint and their stability, and favourably influence crystallization, without lowering electrode life.—M.T.

Arc welding power sources A. Johnson and K. F. Dudey (*Prod. Eng*, 1959, **30.** *Design Digest Issue*, mid-Sept., 172–175).

Joining dissimilar metals–2. J. G. Young and A. A. Smith (*Weld. Met. Fabr.*, 1959, **27,** Aug.–Sept., 331–339) Ni-to-steel and the joining of dissimilar steels are included as is the joining to steel of Cu and its alloys.

On the properties of the austenitic welding electrodes 'E 391' and 'E 891' V. Pilous (*Zváranie*, 1959, **8,** (7), 206–210) The effects of austenitizing and homogenizing treatments on the properties of these electrodes, used for welding stabilized austenitic steels of the 18–8 type, are described.—P.F.

Properties of the new Ni–Cr boron-bearing weld-on alloy 'Real NB' K. Löbl (*Zváranie*, **8,** (8), 227–229) The development and testing of a new alloy of the Colmonoy-6 type, containing, however, more Fe and Cr and less Ni, are described. Cast-on or welded-on layers of the metal have a stable structure up to 700–800°C.—P.F.

Filler wire for welding army ordnance armour S. M. Silverstein, R. P. Sopher, and P. J. Rieppel (*Welding J.*, 1959, **38,** May, 232–240s) Investigations are described with the aim of obtaining ferritic steel filler wire suitable for welding USA Army Ordnance Mn–Mo armour plate. Additions of 0·30% misch-metal to Mn–Ni–Mo–V and Mn–Mo–V ferrite steels were found to increase the resistance to cracking and notch-bar properties (9 refs).

A comparison of certain electrodes for cold welding of cast iron S. A. Narskii and M. A. Grishin (*Svarochnoe Proizv.*, 1959, **32,** (10), 34–37) Electrodes for cast iron are discussed, and the microstructures of the deposited metal are examined.—M.T.

Capillary soldering under protective atmospheres in electric furnaces V. Ruža (*Zváranie*, 1959, **8,** (8), 230–236) The theory, technology, and equipment for industrial free brazing in reducing or inert atmospheres are discussed, and the advantages of this method of soldering or brazing are pointed out.—P.F.

Dip brazing techniques in electrically-heated salt bath furnaces L. B. Rosseau (*Met. Treating*, 1959, **10,** Sept.–Oct., 2–3, 30, 34, 35, 38, 40, 44, 56, 57) The use of salt baths for brazing is reviewed. Equipment is surveyed and alloys for brazing, especially Al alloys are tabulated.

Brazing in electric furnaces (*Wild-Barfield J.*, 1959, **7,** Sept., 10–15) Component design, brazing materials and fluxes, furnaces and atmospheres are reviewed and a table of filler metals is given.

Diffusion bonds Zircaloy and stainless J. M. Gerken (*Metalw. Prodn.*, 1959, **103,** Oct. 23, 1706–1707) A conical joint is made as there is differential expansion, and a vacuum furnace at 1868°F for 80 min, or induction heating at a higher temp. for 2–3 min in helium is used. The yield pressure on testing was 13 200–17 200 psi.

Baking 'the biggest' metal sandwich North American Aircraft Co. (*Metalw. Prod.*, 1959, **103,** Aug. 14, 1244–1245) Production of honeycomb panels 10 ft × 14 ft of a Mo stainless steel is described using furnace brazing.

Bonding of metals H. Schwartz (*Materialprüfung*, 1959, **1,** Sept., 324–326) The influence on bonding strength of such factors as wetting surface pretreatment, surface roughness, and adhesive layer thickness is discussed.—L.J.L.

Adhesive bonding J. C. Merriam (*Mat. Design Eng.*, 1959, **50,** Sept., 113–119, 122–128) Manual No.162.

Oxygen-free fluxes for welding high-alloy steels and alloys B. I. Medovar and S. M. Gurevich (**Avtom. Svarka*, 1955, **8,** (4), 31–41) Oxygen-free fluxes forming neutral welding slags are reviewed. They are especially useful for austenitic steels and can be used with Ti-containing welding rods and resisting hot-cracking. Compositions are given and mechanical properties of welds are tabulated.

Are too many tests hurting welding? (*Steel*, 1959, **145,** July 20, 84–87) Opinions have been collected as to whether the number of non-destructive tests carried out on welds are necessary. Nearly 2/3 of the authorities questioned favoured fewer tests. Many consider welds in mild and structural steels sufficiently reliable. Criticism of porosity is discounted in many cases. Others consider present testing standards necessary to maintain quality. A program is suggested for determining new standards and getting them accepted.—D.L.C.P.

Research into CO_2 arc welding of low-carbon steel with the introduction of a magnetic flux A. G. Mazel', R. P. Burlakova, and K. K. Krenov (*Svarochnoe Proizv.*, 1959, **32,** (8), 15–17) The experiments show that this combined method yields a marked reduction in spattering of the metal and better weld formation by comparison with ordinary CO_2 welding. Special welding wires may be dispensed with and ordinary low-carbon wire used without porosity of the welds, which have good strength and plastic properties. The permanent horseshoe magnet used can be improved upon for flux magnetization.—M.T.

Weldability of 13%Cr steels used for castings V. Pilous and F. Jandoš (*Slévárenství*, 1959, **7,** (5), 191–194) The technology of welding 13%Cr low-carbon steels used in the production of turbines for hydroelectric power stations, as developed on the basis of researches carried out by the authors, is described in detail.—P.F.

An investigation of the weldability of 12%Cr heat-resisting steels M. Kh. Shoroshorov, V. V. Belov, V. N. Zemzin, and I. D. Smirnova (*Svarochnoe Proizv.*, 1959, **32,** (9), 6–10) A study was made of the tendency of a number of such steels to hardening during welding, the effect of the thermal welding cycle and of heat treatment conditions on softening in the high temperature tempering range and the effect of the heat treatment conditions before and after welding on the mechanical properties of the welded joints. The preheat temperature of about 200°C should be lower than the post weld treatment temperature.—M.T.

The weldability of the heat-resisting Cr–W–Mo–V steel 'Skoda T 56' in the forged state V. Pilous (*Hutn. Listy*, 1959, **14,** (5), 429–435) The development of methods suitable for welding the steel is described, and details of the methods adopted are given. The steel contains 0·17%C, 0·34%Mn, 0·24%Si, 1·33%Cr, 0·2%Ni 0·55%Mo, 0·46%W, 0·74%V, 0·01%P max., and 0·020%S max.—P.F.

Reproducibility of the CTS weldability test for low-alloy steels P. H. R. Lane (*Brit. Weld. J.*, 1959, **6,** Aug., 354–361) A co-operative investigation by five laboratories showed such good agreement that the test is considered as suitable for the investigation of cracking in heat-affected zones and as a comparative test for steels, electrodes, and welding procedures.

Long term strength of welded joints at elevated temperatures A. V. Stanyukovich and V. K. Zemzin (*Metallov. Obra. Met.*, 1958, (2), 12–18) Long-time strength of pearlitic and austenitic steels is studied in relation to the conditions of service. The stress systems were arranged parallel and perpendicular to the weld axis and the tests were carried out at 565° and 600°. The electrodes were also varied and the findings are discussed.

Welding properties of chromium–nickel–molybdenum hardenable stainless steels R. H. Kaltenhauser (*Welding J.*, 1959, **38,** May, 228s–231s) Semi-austenitic hardenable stainless steels AM–350 and AM–355 (15½–16½%Cr, 2¾%Mo, and 4½%Ni) are shown to have good welding properties using the same techniques as for the fully austenitic stainless steels.

Special features of the transformation of austenite during fusion welding M. Kh. Shorshorov, B. A. Smirnov, and V. V. Belov (*Svarochnoe Proizv.*, 1959, **32,** (11), 12–15) The heating rate in the Ac_1–Ac_3 range and the time during which the heat-affected zone is above the Ac_3 point basically affect the homogenization of austenite and grain growth, varying with the welding method. Two tendencies are noticeable during welding: (a) in steels with a limited content of carbide formers, the high temperature of the heat-affected zone promotes grain growth and stability of the austenite, and (b) in those with larger contents of carbide formers the degree of homogenization and stability of the austenite is reduced. Anisothermal transformation curves, based on heat treatments, should be used with caution: suggestions for preparation of suitable curves are given.

Testing the weldability of thin steel sheet A. Hrabovec (*Zvár. Sbornik*, 1959, **8,** (2), 220–246) [In Slovak] A survey of the literature on the weldability of steel sheet is made. Detailed experiments by the author designed to ascertain the causes of poor weldability and the occurrence of faults and blemishes due to welding, are described. A simple melting test developed by the Czechoslovak Welding Institute was found to give the most reliable indication of weldability; other tests did not give reliable results.—P.F.

On thermal kinetics in welding under flux A. Schweighofer (*Zváranie*, 1959, **8,** (6), 163–166) A study was made of the temperature distribution and its time dependence in the case of thick steel plate welded by the electroslag method without initial preheating, and near similar welds made by automatic submerged arc-welding with preheating to 340°C.

On the practical utilisation of data obtained in studies of the thermal kinetics in electro-slag welding of thick sheet J. Lombardini (*Zváranie*, 1959, **8,** (6), 167–168) The data obtained by A. Schweighofer (previous abstract) are applied in the development of the technology of welding thick walled steel vessels.—P.F.

Instantaneous inspection of ship welds with scattered gamma radiation J. I. Bujes (*Weld. J.*, 1959, **38,** July, 301s–304s) Laboratory experiments show promise of being able to detect flaws in welds and estimate steel thickness by a technique using no film and working on one side of the hull only. It is based on measuring the intensity of scattered radiation

from a ^{60}Co gamma source with a scintillation counter or other device.—K.E.J.

On the equilibrium in the reactions between slag and metal in the arc-welding process: Part IV A. Bargoue and V. Gottardi (*Riv. Ital. Saldatura*, 1959, **11**, July–Aug., 157–162) To conclude the series the writers examine the influence of the welding speed on the establishment of thermodynamic equilibrium /between the slag constituents and the Si and Mn in the weld metal.

Mechanical properties of metal-arc welds in galvanized mild steel P. W. Jones (*Brit. Weld. J.*, 1959, **6**, April, 175–180) Mechanical tests carried out on hot-dip galvanized plate and sheet showed that weldability and properties were not appreciably affected by the presence of the Zn coating.

Effect of storage time on the hydrogen content and mechanical properties of arc welds made with electrodes W. Hummitsch (*Brit. Weld. J.*, 1959, **6**, April, 155–159) It is shown from the experiments described that dissolved H_2 is evolved during storage to a minimum value, not always sufficient being removed to eliminate all fish eyes. The relationship between tensile test results and storage time is examined for a variety of coatings.

A device for measuring temporary welding stresses K. K. Khrenov and I. M. Zhdanov (*Svarochnoe Proizv.*, 1959, **32**, (3), 16–18) The machine is mainly intended for measurement of longitudinal and transverse stresses in butt joints. Measurement may be carried out close to the weld during automatic welding, without hindrance to the movement of the welding head, and without heat damage to the measuring device. The error due to structural features $< 0{\cdot}06\%$ and the setting error $\sim 0{\cdot}25\%$. The rating plate error of the indicator head reduces accuracy at low stresses, but does not distort the form of the stress curve.—M.T.

Inhomogeneities in the fusion zone of welded joints L. S. Livshits, L. P. Bakhrakh, and S. I. Panich (*Metallov. Obra. Met.*, 1958, (1), 26–29) Inhomogeneities occur in pearlitic steels with different compositions of weld and base metals. They form because of the migration of carbon atoms, in the solid state, from one metal to the other. The direction of the migration depends only on the difference in the amounts of carbide forming elements in the base and weld metals. The welded joint immediately after welding has no appreciable inhomogeneity.

Bond strength of brazed work on steel carried out with brass rods incorporating flux J. Colbus (*Schweissen Schneiden*, 1959, **11**, May, 175–178) Comparative tests with coated brass rods and wires wound helically round a flux showed that the latter showed the best adhesion to steel sheet of various gauges (7 refs).

Brazing under an electric blanket D. E. Wernz and M. Schwartz (*Met. Prog.*, 1959, **75**, May, 109–112) The technique of brazing by enclosing the work in a water-cooled structure with an electrically heated ceramic envelope is reviewed, modifications of the design described and illustrated, and some applications of the process indicated. The brazing cycle, including heat treatment, was carried out in a much shorter time on such work as panels.

Cracking of low-alloy steel weld metal T. E. M. Jones (*Brit. Weld. J.*, 1959, **6**, July, 315–323) A BWRA Report. The effects of variables controlling cooling rate, alloy content, and weld restraint on fissuring are described. The influence of heat-affected zone cracking is considered and a bead-on-plate test for evaluating cracking is described. Degree of fissuring increases with bead size, plate thickness, and weld restraint and is related to Cr and Ni content.

The change in the composition and structure of the cutting zone of austenitic and semi-ferritic steels O. Sh. Spektor (*Svarochnoe Proizv.*, 1959, **32**, (12), 9–12) Marked changes were found to occur in the heat-affected zone of such steels during cutting such as increase in grain size, hardening and tempering of the hardened layer, but cracking was not observed. Impoverishment of the cut edges in alloying elements was observed to a depth of 0·5 mm caused by heterogenous diffusion. Impoverishment increased with the depth of penetration of the cutting oxygen. During submerged arc cutting of slabs and billets, the surface structures which are formed may be disregarded in view of the degree of subsequent heating and deformation during rolling.—M.T.

The effect of the ferritic phase on the properties of the deposited and the base metal of welded joints in chrome-nickel austenitic steels A. E. Runov and K. V. Lyubavskii (*Svarochnoe Proizv.*, 1959, **32**, (9), 15–19) A study was made of the effects of this phase on the long-term strength of austenitic-ferritic metal, of the composition of this metal on the rate of breakdown of the ferritic phase and its embrittlement during stabilization heat treatment, and of the method of producing such metal on the rate of breakdown of ferrite during stabilization and during its dissolution during austenization.—M.T.

Internal-stress distribution of single spot welds in relation to their fatigue life G. Welter and A. Choquet (*Weld. J.*, 1959, **38**, April, 145s–158s) The reasons for the substantial improvement obtained in the fatigue resistance of spot welds by a specific hydrodynamic treatment were investigated in a series of tests using mechanical and electrical strain gauges and extensometers. The tests are described and the results discussed; it is concluded that the improvement is due to the formation of favourable internal-stress patterns.

Joint research into the reproducibility of the test of controlled thermal severity in the study of the weldability of light alloy steels (*Rivista Italiana della Saldatura*, 1958, **10**, Nov.–Dec., 232–241) The Reeve and modified Reeve tests are described and the reasons why they have been replaced by the CTS test are examined. The CTS test is illustrated and researches are described in order to check its reproducibility in different laboratories.

The 'white' band in welding joints of 15Kh1M1F steel B. S. Kasatkin, N. L. Kareta, Yu. N. Bakhnin, and S. I. German (*Avtom. Svarka*, 1958, (12), 12–16) The formation of 'white' bands in the zone adjoining the weld is related to the residual plastic deformation at the edges of the weld metal in the region heated below the Ac_1 point. The metal in the white strip has a distorted crystalline lattice and an increased C content in solid solution and also N. The nature of the 'white' strips in the 'ageing' zone in welds is similar. The main cause of their formation is the residual plastic deformation and not the rapid cooling rate from the temperature below the Ac_1 point.

Defects in welding using the automatic submerged arc welding process O. Grossi (*Rivista Italiana della Saldatura*, 1959, **11**, Jan.–Feb., 3–18) This paper deals with the defects occurring in submerged arc welding, essentially caused by inadequate choice of materials, imperfections in edge preparation or incorrect welding techniques. The author indicates the precautions to be adopted, in the cases considered, in order to obtain good welds.

Braze bonding stainless-steel fuel elements for nuclear reactors P. P. King and R. K. McGeary (*Weld. J.*, 1959, **38**, June, 241s–246s) In the technique developed, an electroless plating with Ni containing P serves as the brazing alloy when heated to 1850–1900°F in a dry H_2 atmosphere. Advantages are listed and corrosion properties of this type of bond are given.—A.G.

New air- and water-cooled cutting torch N. M. Varfolomeyer (*Eng. Digest*, 1959, **20**, July, 284–285; *Svarochnoe Proizv.*, 1959, (6), 34–36) This oxygen torch reduces distortion of work by incorporating water- and air-cooling arrangements around the cutting zone. Some results are reported.

Tungsten-arc cutting of stainless steel shapes in steel warehousing operations J. D. Wait and S. H. Resh (*Weld. J.*, 1959, **38**, June, 576–581) By the introduction of tungsten arc cutting it has been possible for a steel warehouse to supply stainless steel to customer's shape requirements. Some examples are given.—A.G.

General recommendations for oxygen cutting of mild and low alloy steels IIW Commission I (*Soud. Techn. Connexes*, 1959, **13**, March–April, 113; *Rivista Ital. Saldatura*, 1959, **11**, March–April, 68–69) Recommendations are made regarding operating conditons and material to be used for oxygen cutting of steels $R < 48$ kg/sq.mm or $R < 52$ kg/sq.mm but with $< C 0{\cdot}20\%$. Precision is stated on the basis of thickness to be cut.—R.P.

MACHINING AND MACHINABILITY

The mechanics of orthogonal machining W. B. Palmer and P. L. B. Oxley (*Inst. Mech. Eng. preprint*, 1959, pp.18) A method of observing the cutting process during slow orthogonal cutting of mild steel was devised and the results could not be reconciled with the ideal theory of plasticity. The work hardening effect was then taken into account and a new picture of the cutting process was arrived at.

Looking 10 years ahead in machining M. E. Merchant (*SAEJ*, 1959, **67**, Aug., 78–80) Based on a paper presented to the society; aspects of machining, cutting speeds, tool improvement cutting aids and other matters are referred to.

Are you keeping up with machining technology? (*Steel*, 1949, **145**, July 13, 98–99) Examples are briefly given of choice and treatment of parts and tools.

Tools for machining operations F. Pühler (*VDIZ*, 1959, **101**, Nov. 21, 1622–1624) Cutting materials, operations, and tools are discussed, with reference to recent developments (28 refs).

Machining with ceramic tools at the works of Alvis Ltd (*Machinery*, 1959, **95**, Oct. 7, 692–694) A table comparing sintered oxide with carbide tools in the machining of 16 parts is given.

System and methods of testing machine tools J. Tlusty (*Microtecnic*, 1959, **13**, Aug., 162–178) Accuracy, output, life, adaptation to the operator and economy are set out as the main qualities and system of testing for accuracy, stability against self-excited vibration, testing of main and feed drives, operating and controlling elements and circuits, and loading, clamping, lubricating, and cooling devices, safety guards, and chip removal is described.

High speed machining of cast iron pulleys Tarex Ltd (*Machinery*, 1959, **95**, Oct. 7, 698) A note on the use of a Tarex TAR–L 42MPS automatic with carbide tools.

Economies obtained with ceramic tools B. E. Storrs (*Machinery*, 1959, **95**, Sept. 30, 629–632) The use of cemented oxides in conventional machine tools shows advantages of which examples are given, and high speeds and power ranges are not essential for their effective use.

AM-350 stainless steel P. R. Arzt, J. V. Gould, and J. Maranchik jun. (*SAEJ*, 1959, **67**, July, 62–63) Machinability has been measured by turning, drilling, and tapping tests, the data for which are diagrammatically displayed.

Air Force programme evaluates the machining characteristics of a stainless steel P. R. Arzt, J. V. Gould, J. Maranchik, jun. (*SAEJ*, 1959, **67**, Aug., 87–89) A large table of data for turning, face and side milling with carbide tools, and milling with high speed steel and carbide tools, slotting, drilling, and tapping is given with a note on turning tests. The steel was A–286.

New fabrication techniques R. O. Williams and P. E. Berghausen (*ASM compilation from Southwestern Metal Congress*, May, 1958 [1959], pp.62). **Theory and application of electro-discharge machining** (1–13) A comparison with other forming processes is made. **High speed cutting** E. K. Henriksen (14–18) Notes on current theories. **The chemical milling process and its primary applications** R. L. Chandler and G. E. Boehmer (19–23) A brief review. **Forming at elevated temperatures** H. B. Osborn, jun. (31–35) An account of warm forming processes, especially for steel (SAE 1020). **Adhesive bonding of primary aircraft structure** W. S. Hay (36–47). **Some of the growing pains of the B-58 sandwich construction** E. H. Watts (48–53). **A new concept of weld metal for high strength fabrication** D. C. Smith and W. G. Rinehart (54–62) Hardness and strength of welded steels are discussed and structures are shown. Three commercial electrodes for SAE 4130, 4140, and 4340 steels were compared.

Relation between the cutting speed and the cross-section of the chip as depending on the cutting force. Economics of high-speed cutting I. Bucur (*Metalurg. Constr. Masini*, 1959, **11**, (5), 398–402) The variation of the cutting force as a function of the cross-section of the chip and the speed of cutting are calculated and

indices for various steels and irons are given. An economic analysis shows that the optimum cutting speeds lie between 250 and 400 m/min.

Friction of relief face of cutting tool M. Okoshi and T. Sata (*Sci. Papers Inst. Phys. Chem. Res.*, 1958, **52,** Dec., 216–223) [In English] Comparisons with the rake face are made and explanations of the phenomena are offered.

Modification to a vertical boring mill for machining the large bell and hopper of the new F blast furnace N. P. Naik (*Tisco*, 1959, **6,** July, 169–189) A full account is given with illustrations and plans. The large bell was imported but a spare was constructed.

Transfer line machines, several cast iron and aluminium parts (*Iron Age*, 1959, **183,** April 23, 114–115) A description is given of General Motors automatic transfer line which can machine three types of cylinder head in either cast iron or Al. Changeover time is less than half a day.—A.G.

Difficult milling operations performed with carbide cutters C. Sharp and B. Main (*Machinery*, 1959, **95,** Aug. 19, 284–286) Alloy and stainless steel finishing is described, the conditions being set out and experiments being reported.

Turning alloy steels with ceramic and carbide tools (*Mech. World*, 1959, **139,** April, 174–175) PERA studies are reported. Comparative tests of US and British tools and tips were made.

Ceramics thread hardened steel shafts A. O. Smith Corp. (*Metalw. Prod.*, 1959, **103,** June 12, 1034) A brief account of work on the cutting of threads on AISI4140 steel bars using proprietary bits.

Chrysler report on ceramic tools B. C. Brosheer (*Metalw. Prod.*, 1959, **103,** June 19, 1074–1078) Increased tool life and improved control have given major savings with little or no increase of cutting speeds over those used for carbides. Cratering and wear of bits turning pearlitic malleable castings are shown and various jobs are described.

Metal cutting J. M. Galimberti, R. S. Hahn, H. J. Siekmann, and E. G. Thomsen (*Mech. Eng.*, 1959, **81,** Sept., 57–60) A literature review 1957–1958 (40 refs).

Investigating dispersion hardened cutting alloys A. D. Klement'ev (*Chem. Metallurg.*, 1959, (3), 77–83) Dispersion hardened Fe–Co–W alloys may be used as suitable additions to the alloys investigated, increasing their strength and red hardness over and above that of the normal high-speed steels.

Uniform type 431 stainless pays big dividends (*Western Metalw.*, 1959, **17,** May, 41) For machining aircraft parts Carpenter Mel-Trol 431 stainless steel has been selected because of its constant analysis and the absence of inhomogeneities. These benefits are achieved by precise quality control, high speed analysis, and the use of a patented ingot mould.

Vasco jet 1000 die steel P. R. Arzt, J. V. Gould, and J. Maranchik, jun. (*SAEJ*, 1959, **67,** June, 82–85) Machining properties were tested by turning and milling and the results of the tests are shown graphically. Tool life curves are shown.

Attachment caresses surfaces to a controlled finish (*Steel*, 1959, **145,** July 27, 110–112) The Microstoning process and tool attachment are described. Precision finishes are obtained by means of a light-pressure high-frequency oscillation process using diamond surfaces.

Machining and grinding Ni-resist irons and Ni-resist ductile irons *International Nickel Co. pamphlet*, 1959, pp.20) Recommended tools and tool settings are included.

Liquid honing F. Neuberger, L. Moeckel, and L. Roetz (**Fertigungstechnik*, 1957, **7,** (9), 413–417) A review of the process and the materials used and the sort of precision attained is given. An experimental trial of the method for five finishing processes is described and the treated parts are shown and their finish evaluated.

New erosion machine for forging dies Wickman Ltd (*Metalw. Prodn.*, 1959, **103,** Sept. 11, 1451, 1453, 1455) The Erdomatic machine for forging die blocks up to 28 × 16 × 15 in. is described. It uses electro-erosion machining with 13 or 4·5 kW generators.

Grinder takes on roll form job (*Iron Age*, 1959, **183,** April 23, 116) The process described enables multiple grooves and forms to be ground from the solid roll in one operation. A hardened steel or carbide roll of the desired profile dresses a grinding wheel which in turn grinds the work-piece.—A.G.

How air speeds chip removal (*Iron Age*, 1959, **183,** May 28, 110–111) A system has been devised for the removal of chips from two lines of automatic screw machines. It comprises automatic conveying, crushing, wringing to recover oil, and pneumatic discharge into a storage bin.

Scrap handling—problem or profit? (*Steel*, 1959, **144,** June 22, 98–99) The value of scrap-handling conveyors in machine shops is explained and illustrated.—D.L.C.P.

New developments in spark-erosion machining H. Opitz (*Microtecnic*, 1959, **13,** Aug., 147–153) The effect of variation in the working gap was examined, it was also found that the choice of workpiece material is important and quantitative explanations of transformations in the temperature-affected zone were also obtained.

Improving spare part production I. E. Moshkevich, V. S. Gudynovich, and Kh. P. Zaitsev (*Stal'*, 1959, (11), 1054–1055) General recommendations for improving the precision of castings and forgings to reduce machining are made.

Grinding G. Reichenbach (*Mech. Eng.*, 1959, **81,** Sept., 62/63) A literature review of chip formation, residual stresses, and abrasive wear for 1958 (8 refs).

Machining in barrels D. J. Fishlock (*Met. Ind.*, 1959, **95,** Sept. 11, 95–97) A final article on machines available, and the finishing of steel tubes as an example.

Investigation of the grain tenacity of abrasives K. Giesen (*Radex Rundsch.*, 1959, Oct., 640–659) Different methods of pulverizing abrasives for determining grain tenacity are described, and the various types of equipment illustrated. Methods are evaluated and compared, and sampling and testing recommendations are made.

Let's take the guesswork out of inspection J. S. Gantt (*Metalw. Prod.*, 1959, **103,** June 12, 1035–1040) A discussion of tolerances, the reproducibility of measurements with the same and different gauges and the degree of uncertainty between satisfactory and unsatisfactory parts in borderline cases.

CLEANING AND PICKLING

Iron Age Metal Cleaning and Finishing Handbook (*Iron Age*, 1959, **183,** June 4, 125–145) Data are tabulated for iron and non-ferrous metals.

Importance of preparing ferrous surfaces before applying protective coatings (*Acciaio Costr. Met.*, 1959, **11,** May–June, 11–14) Various types of pretreatment are compared including brush-off blast cleaning, treatment with a drying oil, basic zinc chromate and a vinyl-butyral wash coat.

Surface finishing stainless steels L. F. Spencer (*Met. Fin.*, 1959, **57,** July, 48–53, 58) Abrasive and polishing methods are reviewed.

Choosing surface finishes for small tubing J. H. Black (*Mat. Des. Eng.*, 1959, **50,** July, 101–103) Finishes classified as pickled, bright, polished, tumbled, sanitary, and bright pickled are described.

Surfacing (*AWS bibliography*, 1958, pp.51) References are given to papers appearing in the *Welding J.* since 1937, in chronological order.

Some recent developments in metal degreasing (*Machine Shop Mag.*, 1959, **20,** July, 376–381) An illustrated review.

Thirty years of metal degreasing (*Met. Finishing J.*, 1959, **6,** June, 246–247) The introduction of a new drying agent for use with trichlorethylene is noted.

Automatic plant for surface treatment of metals H. Anders (*Ind. Fin.*, 1959, **11,** June, 35–36; from *Metall Reinigung und Vorbehandlung*, **8,** (2), 20) Dip and spray degreasing process, acid cleaning and spray chamber design, and multi-zone installations are briefly discussed.

The progress of mechanical descaling in England H. F. Sanderson (*Wire Ind.*, 1958, **25,** Dec., 1137–1138) Types of descaling machines are described and the problem of subsequent lubrication is considered. Although slower drawing speeds are necessary, mechanical descaling eliminates costly pickling and effluent disposal.—A.G.

Descaling application and formulation (*Mech. World*, 1959, **139,** Sept., 387–388) An account of NaH, NaOH, and other descaling methods from the theoretical standpoint, and of the acid and electrolytic pickling of stainless steels. Non-ferrous materials are included.

Descaler improves quality of forged well rods (*Steel*, 1959, **145,** July 13, 117) Treatment by Youngstown Sheet & Tube Co., Texas, is outlined.

Precision barrel finishing L. F. Spencer (*Machine Design*, 1959, **31,** Sept. 3, 156–160) A review of media and time cycles with notes on the effects of part shapes.

Continuous shot blasting of steel sheet J. A. Edwards (*Sheet Met. Ind.*, 1959, **6,** Oct., 637–638) Details of plant installed in the USA which eliminates pickling of hot-rolled sheet and operates at a speed of 60–180 ft/min.

Results of experiments on shot blasting of cast iron with various grits A. D. Morgan and J. M. Greenhill (*BCIRA J. Res. Dev.*, 1959, **7,** Aug., 790–798) An investigation of the effects of various types of shot-blasting grits on the occurrence of enamel boil defects is described. Iron samples of four different compositions were treated at various plants and, the nature of the 'cleaned' surfaces was examined. It was shown that grit containing a high proportion of fine material gave a more satisfactory finish that coarser grits; application of the findings in an industrial plant reduced the boil and pinhole defect scrap-rate.—O.J.H.

Needles add to air gun output (*Iron Age*, 1959, **183,** April 23, 109) A lightweight air-operated unit is described which employs rapidly reciprocating hardened steel needles for cleaning and descaling.—A.G.

Notes on grit blasting (*Fonderia*, 1958, **7,** Oct., 427–433) This article draws attention to the importance of correct choice and use of metallic grit both in pickling and shot-peening operations if satisfactory results are to be achieved.

What makes a good steel shot C. E. Carlin (*Met. Progress*, 1959, **75,** June, 82–85) The effects of the life, hardness, and size distribution of shot for blast cleaning or peening, on the efficiency of blasting operations are discussed, and methods of evaluation are assessed.

Barrel-finishing in the foundry A. Arendt (*Fond. Belge*, 1959, **29,** Oct., 249–252) The mechanism, operation, and precision control of Belgian, British, and American types of equipment for ten classes of finishing, preparatory to painting or electroplating are described and compared.—S.H.–S.

A high-output plant for chemical cleaning of sheet steel Yu. A. Avikson (*Svarochnoe Proizv.*, 1959, **32,** (12), 29–30) A description is given of the plant which includes a sheet roller straightener, a pickling plant, and washing, neutralizing, and passivation plant and the necessary conveyors and stackers.—M.T.

On the mechanism of electrolytic reduction of oxygen in iron A. S. Afans'ev and V. V. Shevchenko (*Ukrainskii Khim. Zhurnal*, 1959, **24,** (2), 158–161) The process of electrolysis is suitable for accumulating and maintaining H_2O_2 in the cathode liquid during electrolytic reduction of oxygen in alkaline solns. During reduction of oxygen from oxidized and rusted steel in a 0·1 N KOH solution at 0° at is possible to detect H_2O_2 in the cathode liquid by three independent methods: by means of aurichloride ions in the alkaline electrolyte, by dissolving TiO_2 after neutralization of the alkaline electrolyte by sulphuric acid: and by the more sensitive iodine method. The presence of H_2O_2 plays an important role in the electrolytic reduction of an oxidized steel surface in alkaline solutions.

Electropolishing in production (*Metalw. Prodn.*, 1959, **103,** Aug. 21, 1280–1281) A brief review.

Electrolytes for the electro-chemical polishing of steel G. P. Maitak and G. S. Tret'yakova (*Zhurn. Prikl. Khim.*, 1959, **32,** (5), 1060–1065) Carbon, high carbon, and stainless steels are electrochemically polished at 18–25° in electrolytes consisting of mixtures of H_2SO_4 and H_3PO_4 with additions of inhibitors. The optimum composition of these electrolytes for each

of the types mentioned above and the best conditions for the opeation are given in detail.

Hot dip galvanising (*Proc. 5th International Conf.*, 1958, pp.343) **Efficiency of hydrochloric acid pickling** F. Sjoukes (3–16) A formulation of acid loss mechanisms with a recommendation for frequent liquor analyses. A brief description of pickling trials is given in an appendix. **The reclamation of hydrochloric acid from spent pickle liquors** R. Haarmann (17–20) Recovery by thermal dissociation of $FeCl_2$ is described.

Acid pickling G. F. Whitmore (*Inst. Vit. Enamal. Bull.*, 1959, **9,** June, 127–135) A lecture. A general outline of the chemistry of the process and of the type of plant used is given, including fume extraction and waste disposal and acid recovery processes.

Pickling and acid dipping of metals J. B. Mohler (*Met. Fin.*, 1959, **57,** June, 63–67) A review of agents used and methods for various metals including stainless steels.

Pickling rate of hot-rolled steel strip B. L. Le Bas (*Sheet Met. Ind.*, 1959, **36,** June, 401–406, 414) Scale formation, scaling, coiling temp., cooling rate, pickle line variables (scale-breaking, acid concentrations and temp.), and other factors are considered.

Velocite as foaming agent in hydrochloric acid and chromium solutions A. Z. Grebenshchikova and F. P. Shavkunova (*Stal'*, 1959, (9), 828–829) The use of a foaming agent to restrict evolution of acid fumes is described. In a number of trials in etching and wire plating baths, velocite, a petroleum distillate, at the rate of 1·5–2 kg/m² of bath surface was the most effective agent used. It has no effect on plating quality.

First West Coast continuous anneal-pickle line treats cold rolled stainless strip W. Durkee (*Western Metalw.*, 1959, **17,** June, 50–51) A Los Angeles plant is described.

The treatment of spent pickling solutions and waste waters in the iron and steel industry using ion exchange membranes H. Quitman (**Draht*, 1959, **10,** May, 225–229) The development of an electrolytic membrane cell for the recovery of H_2SO_4 and conversion of iron salts to hydroxide sludge is described. Complete purification is secured with a conventional exchange-process tower plant for effluent treatment. Costs are indicated.

Review of recovery of spent pickling solutions by ion exchange G. von der Dunk (*Stahl Eisen*, 1959, **79,** Oct. 1, 1427–1430) The action of ion-exchange resins is explained and a number of methods for the recovery of spent pickling solutions using selective ion-exchangers and in some cases also electrolysis are described. The costs of such a process are discussed, the running expenditure is tolerable, but the capital investment is extremely high.—T.G.

New developments in the regeneration of used pickling baths G. Labergere (*Met. Constr. Mécan.*, 1959, **91,** 541–543, 545, 547; 665–673) Theoretical data on the crystallization of $FeSO_4$. $7H_2O$ are followed by an account of 'valve-pickling' and its application to the Blaw–Knox–Rüthner pilot installation. A summary is then given of the report: 'Evaluation of the Blaw–Knox/Rüthner Pilot Plant Programme' given at the General Meeting of AISI in 1958, and reproduced in *Blast Furnace and Steel Plant*, June 1958.

Optimized metal finishing recovery system W. F. Swanton (*Plating*, 1959, **46,** Aug., 919–921) The principle of a system at present in operation, which solves the waste disposal problem for the operation, recovers chemicals formerly lost in drag-out, maintains the bath at a steady operating temp., reduces the water consumption and utilizes waste process heat, is described. An optimized system, which is a development of the present one, is then discussed.—O.J.H.

Purification of waste liquors from stainless steel pickling A. V. Evlanova, S. N. Stefanovich, and A. A. Mokina (*Stal'*, 1959, (10), 956–959) Studies on lime neutralization and concentration to produce crystalline $FeSO_4$. $7H_2O$ are reported. Waste liquors from stainless steel containing HNO_3 contain only ferric salts and do not crystallize on concentration. The products in this case are unsuitable for use as heat insulation.

Treatment of waste acid and effluent from the continuous strip pickling lines of the Brinsworth Mill of Steel, Peech and Tozer (*Sheet Met. Ind.*, 1959, **36,** May, 321–328, 340) The sulphuric acid regeneration plant built to handle the spent pickle liquors from continuous strip lines are described. The shock cooling process is used—the precipitation of iron from solution as ferrous sulphate.—D.L.C.P.

PROTECTIVE COATINGS

Science for electroplaters, 48: Electrodeposited metals L. Serota (*Met. Fin.*, 1959, **57,** June, 90–93, 96) Various general concepts are discussed in general terms.

Protective metallic coatings C. L. Faust (*Metals for supersonic aircraft and missiles. Proc. Conf. Albuquerque* 1957, *sponsored by ASM and Univ. New Mexico, ASM publication*, 1958, pp.432; 170–201) The properties of plated and cladding materials, thin application, oxidation notes, stress rupture values, and weight losses in molten or gaseous MoO_3 are given.

Science for the coatings technologist. XIII. Additives: Stabilizers E. S. Beck (*Met. Fin.*, 1959, **57,** May, 59–62, 67; July, 65–69) Metal salts, polymers, and synthetics are reviewed.

Review of local authority bye-laws on finishing trade effluents in South Wales Lord Meston (*Prod. Fin.*, 1959, **12,** Aug., 72–76, 79) Glamorgan, Carmarthen, and Pembroke are covered.

Alkaline chlorination of cyanide wastes and reduction of chromium wastes with sulphur dioxide J. L. Beals (*Plating*, 1959, **46,** Aug., 922–923) The chemical processes involved are described, and the general arrangements for flow and batch methods of treatment are considered. The greater control obtainable by batch treatment is stressed.

Design and operation problems of a continuous automatic plating waste treatment plant N. H. Hanson and W. Zabban (*Plating*, 1959, **46,** Aug., 909–918) The theoretical basis of water conservation by automatically controlled counter-current multiple rinsing, and the methods of treatment for the removal of cyanides, Cr^{6+}, oil, and other wastes are described in detail'—O.J.H.

CLAD SHEET AND HARD-FACING

Hard surfacing increases service life of edger rolls (*Ind. Heat.*, 1959, **26,** June, 1172–1173) Hard-surfaced mild steel edger rolls and bearing buttons on a steel strip line, last more than 20 times as long as unprotected alloy steel parts. The protective metal is Colmonoy R No.6—A Ni base surfacing alloy containing chromium borides, and carbides; it is applied by the Sprayweld Process.—D.L.C.P.

Wear-resistant surfacing with a horizontal laminated electrode B. M. Kontorov and N. V. Popova (*Svarochnoe Proizv.*, 1959, **32,** (9), 27–30) The principles of the welding method and the equipment required are described as, well as the surfacing technique Its industrial applications and the technical economics are also discussed. The laminated electrode is placed on a bed of flux on the face to be surfaced and covered with a layer of flux. The underside of the plate is treated with a layer of alloying material in paste form. The arc is struck between the laminated electrode and the component to be surfaced.—M.T.

Automatic hardsurfacing and you R. G. Alison (*Can. Metalw.*, 1959, **22,** June, 40–41) A general account of the process using fluxes and mild steel electrodes. The surfacing of steel mill rolls is mentioned.

Chromizing in a vacuum F. Princ and V. Navara (*Czech. Heavy Ind.*, 1959, July, 20—27) The vacuum-chromizing process developed in Czechoslovakia is described and explained. The components are embedded in Cr powder in a retort, and after evacuation the assembly is maintained at 1050°C for 8–10 h. Advantages are: high quality layer in shorter time than other processes, low powder loss, less danger than in using gases (e.g. H_2). Chromized steel parts may be cheaper than parts made of brass.—D.L.C.P.

Improvement in metal diffusion techniques (*Corr. Techn.*, 1959, **6,** Sept., 267–268) An account of the Dicrom process of surface Cr diffusion with corrosion-test specimens illustrated.

The Dichrom process (*Auto. Eng.*, 1959, **49,** Aug., 292–292) An account of a chromium diffusion process giving a surface of practically pure Cr and highly resistant to oxidation and sulphur-containing gases is given.

Increasing chemical resistance of steel chromided by diffusion N. F. Vyaznikov and A. N. Popandopulo (*Metallov. Obra. Met.*, 1958, (3), 61–62) Experimental findings show that hardness and corrosion resistance after chromiding and Cr cementation are increased. On exposure to sea water, chromided specimens show traces of pitting corrosion after three days, while specimens additionally case-carburized do not show any affect after ten days. Case-hardening reduces the porosity of the chromided layer.

Chrome coating for boiler steel Metal Diffusions Ltd (*Elect. Times*, 1959, **136,** Aug. 13, 42) A note on the 'Dicrom' diffusion chromizing process giving a surface purity as high as 96%. The process can be used to produce Cr foil.

Protection of rods on EI 723 steel from high temperature oxidation T. I. Volkova and Yu. N. Griboedov (*Metallov. Obra. Met.*, 1959, (5), 37–40) A diffusion Cr coating in a mixture of 60%Cr powder of less than 60 mesh, of 39%Al_2O_3 and of 1%NH_4I prevents the scaling of steel up to 550° without causing any appreciable reduction in the relaxation strength.

Improving wear resistance by hardfacing by welding E. N. Gregory (*Eng. Mat., Design* 1959, **2,** Aug.–Sept., 425–429) Facing metals and welding methods are reviewed.

Hard-surfacing shaker screens for uranium mines G. Giangrande (*Machinery*, 1959, **95,** July 1, 16–17) Mild steel grids surfaced with a medium-alloy steel by submerged arc welding are shown, the welding process being outlined.

A process of siliconizing the surface of sheet steel or strip by reduction of silicon tetrachloride in the electric arc and attempts on the reduction of titanium tetrachloride C. Schaarwachter and W. Schaarwachter (*Forsch. Wirts. Nordrhein-Westfalen*, No.297, 1958, pp.22) Into an arc struck between a W electrode and the steel to be siliconized a mixture of $SiCl_4$ and H_2 was blown. The heat of the arc effects a reduction of $SiCl_4$, silicon is deposited as a black, amorphous film on the steel. If the steel base is heated to 700–900°C during this reduction process, the silicon film can be easily removed, but if the steel base is heated to 1200°C diffusion coatings 0·005–0·05 mm thick are formed in 15–120 sec.—T.G.

Construction of a continuous automatic line for the production of copper-steel rolled material V. F. Agapov (*Stal'*, 1959, (10), 936) A note from Magnitogorsk. The series of operations is set out.

New developments in high temperature ceramic coatings F. D. Shaw (*Met. Treating*, 1959, **10,** July–Aug., 2–3, 34) A review including notes on performance.

Ceramic coated furnace rolls insure better silicon strip (*Steel*, 1959, **145,** Sept. 28, 134, 137) The material is applied as powder with a torch and roll build-ups and dents and dimples are largely eliminated in the finished sheet.

Carbide deposit ups tool life R. H. Eshelman (*Iron Age*, 1959, **133,** May 21, 152–153) The advantages of spark deposition of tungsten carbide on tool surfaces are discussed; a 0·0004 in. deposit giving the best results.—A.G.

PROPERTIES AND TESTS

Interferometer for the inspection of large surfaces (*Machinery*, 1959, **94,** June 3, 1261–1262) A NBS design is shown detecting irregularities of ~10 micro-in. on 36 in. long specimens.

Contribution to the examination, control, and prevention of defects by the Federal Institute for Material Testing and Experimentation (*Schweiz. Arch. Wiss. Techn.*, 1958, **24,** Dec., 387–396) This paper is a general summary of the work carried out by the Institute (EMPA). Defects dealt with include those due to mechanical action, corrosion, heat, light, himidity, biological action, and ageing. Brief mention is made of the methods used (31 refs).—R.P.

The slope of the bearing area as a measure

of the surface texture M. Ehrenreich, (*Microtecnic*, 1959, **13,** April, 93–98) Surface finish of rebored cylinders is assessed by a new analysis of the bearing area curve which is claimed to give a better criterion than CLA or RMS indices.

The strength of steel during the process of the transformation of austenite during welding N. N. Prokhorov, E. L. Makarov, and B. F. Yakushin (*Svarochnoe Proizv.*, 1959, **32,** (8), 12–15) Mechanical properties were tested at various moments during the thermal welding cycle at deformation rates between 22 and 0·00015 mm/sec. It is shown that resistance to deformation along the grain boundaries varies with the change in the ductility of the intercrystalline layers and the rate of deformation. At high temps. and low ductility of the intercrystalline layers the stress release period on the grain boundaries amount to 1×10^{-2} to 1×10^{-1} sec. The advance of deformation of the grain boundaries and intercrystalline breakdowns can in this instance occur at high rates of loading. This conforms with the phenomenon of hot crack formation during welding, when in the range of solidification temperatures the rates of deformation are proportional to the high rates of change in temperature in relation to time, i.e. 100–200°/sec. During the breakdown of austenite the intercrystalline layers have ductility which rises considerably, and the stress release period on the grain boundary in this instance is about 1×10^{2}–1×10^{6} sec. so that deformation on the grain boundaries and intercrystalline breakdowns can only occur at low velocities. Such breakdowns therefore occur only as cold-cracking during the breakdown of austenite. Thus mechanical properties of steel, heat-treated in accordance with the thermal velocities, may be used for relative assessment of resistance to cold-crack formation of the base metal during welding.—M.T.

Investigation of deformation processes in Armco iron by means of internal friction at megacycle frequencies W. J. Bratina (*Canad. J. Phys.*, 1959, **37,** May, 579–590) Explanations of the observed phenomena are given in terms of magnetic domain theory and dislocation mechanisms.

Mechanical properties of iron and some iron alloys while undergoing allotropic transformation M. de Jong and G. W. Rathenau (*Acta Met.*, 1959, **7,** April, 246–253) An examination of the plasticity of pure Fe, Fe containing 0·008 wt·% N and Fe with 0·2 wt·%C showed this to be unconnected with creep. Elongation is a linear function of applied stress. When transforming pure coarse-grained Fe in a steep temperature gradient along the axis of the specimens, maximum elongation at zero external stress is $\Delta V/V_2$ (relative difference of specific volume). No influence of stress on maximum change of length was observed for the $\delta\rightarrow\alpha$ transformation (16 refs).

The influence of the form of the transverse oscillation on the damping factor A. P. Yakovlev (*Zavods. Lab.*, 1959, (2), 206–208) Specimens of three sizes were prepared from metallo-ceramic materials. (3·5×13×196, 4×15×295 and 4×15×450 mm). A description of the set-up and of the oscillator is given. It can be seen from the graphs obtained that for the same maximum load the logarithmic decrement is reduced, with an increase in dimension in the form of the transverse oscillations. Thus a decrease of approximately 14% occurs with the second specimen, and a further decrease of approximately 17% with the third. In analyses of machine components for inherent resistance to vibration it is necessary to take into account the logarithmic decrement and also the increase in the complexity of the form of the transverse oscillations.

Direct experimental evidence for dislocations P. B. Hirsch (*Met. Rev.*, 1959, **4,** (14), 101–140) A review (96 refs).

Observation of paired screw dislocations in iron whiskers E. W. Muller (*J. Appl. Phys.*, 1959, **30,** Nov., 1843–1844).

The influence of solute atoms on the damping due to dislocations in iron alloys P. M. Robinson and R. Rawlings (*Phil. Mag.*, 1959, **4,** Aug., 938–947) Effects of Si and O are studied.

The dislocation structure of slip bands in iron J. R. Low jun. and R. W. Guard (*Acta Met.*, 1959, **6,** March, 171–179) Observations on the dislocation structure of single crystals of Fe–3¼%Si by an etch-pit technique showed (a) arrays viewed normal to the edge component are straight but not co-planar, while arrays where the screw component emerges from the surface show much curvature (b) observations made in the slip plane indicate that the motion of the screw components is much more limited than that of the edges. It is concluded that the observations can best be explained by the double cross-slip model of a slip band (11 refs).

On blocking of dislocations by cavities and small particles of precipitate P. Coulomb (*Acta Met.*, 1959, **7,** Aug., 556–559) [In French] An analysis of a crystal in which the dislocations are blocked by a ring of small cavities is presented and the effects of thermal agitation and applied stress are studied. The heat of activation is found to be a linear function of applied stress as previously suggested. Rings of small particles are analysed similarly.

The energy of formation of a vacancy in a metal Wang Yung-chiang (*Acta Phys. Sinica*, 1959, **15,** Sept., 469–474) The energy is calculated from surface tension values, its ratio to energy of self-diffusion is 0·43 and it is a periodic function of atomic number.

Arrangement of dislocations in polycrystalline metals and their relation to the stress-strain curve M. J. Whelan (*Rev. Mét.*, 1959, **56,** July, 153–162) An investigation was made on polycrystalline specimens of austenitic stainless steel for various deformation values, using the transmission electron microscope technique. Dislocations were in the main concentrated at the grain boundaries for <1% deformation; for 1–2% deformation irregular networks occurred, clearly formed by interaction between the concentrations of dislocation and individual dislocations from other slip systems. With greater deformation, the density of the dislocations in the network increased (17 refs).

Disintegration of iron-52 and iron-53 J. O. Juliano, C. W. Kocher, T. D. Nainan, and A. C. G. Mitchell (*Phys. Rev.*, 1959, **113,** Jan. 15, 602–608).

Mathematical determination of internal stresses in ingots and forgings L. Prašek (*Hutn. Listy*, 1959, **14,** (6), 489–493) The distribution of temperatures and internal stresses arising from the non-uniform reheating of ingots is calculated, the ingot being replaced by an endless cylinder, the surface being cooled at a constant rate. It is assumed that the material constants and thermal parameters are independent of time and temperature. Diagrams for a rapid calculation are given.

Dependence of the asymmetry index of the $K\alpha_{1,2}$ line of iron on the concentration of silicon in iron-silicon alloys K. M. Kolobova (*Trudy. Inst. Fiz. Met.*, 1959, (22), 51–54) The materials investigated consisted of pure iron and Fe–Si alloys with 9, 17, 25, 50, and 70 atomic %Si. The method of investigation is described. The findings show that the initial cause of the asymmetry of the line in the transitional elements of the iron group is the presence of non-compensating 3d electrons in the atoms of those elements.

Structure of the energy spectrum of electrons in the iron-chromium alloys N. D. Borisov, V. V. Nemoshkalenko, and A. M. Fefer (*Izvest. A.N. Ser. Fiz.*, 1959, **23,** (5), 573–577) The $\alpha\rightarrow\gamma$ phase transformation of alloys of the Fe–Cr system is accompanied by a change in the crystal lattice and in a number of physical properties. The investigation concerned in particular the X-ray emission K_{β_5} band of Cr and Fe in these alloys. The data have been tabulated of the width of the K_{β_5} line for pure iron, with increasing Cr content at different temperatures.

Thermal stresses owing to a hot spot in a rectangular strip C. W. Nelson (*J. Appl. Mech.*, 1959, **26,** Dec., 488–490) The case is evaluated for an infinite strip.

Activity of carbon in liquid iron alloys. I. Effects of nickel cobalt, tungsten, and molybdenum on the activity of carbon in liquid steel T. Fuwa and J. Chipman (*Tetsu to Hagane*, 1959, **45,** June, 600–607) The equilibrium at 1560°C between CO–CO_2 mixtures and C in liquid iron alloys (0·1–0·3%C) is represented by an equation. The effects of various elements on the activity of carbon are given (in terms of 1% alloy and the logarithm of the coeff.) as: C+0·200, Ni+0·012, Co+0·012, W−0·003, Mo−0·009 (20 refs).—K.E.J.

Activity of silicon in liquid iron and the influence of manganese and phosphorus B. M. Lepinskikh, O. A. Esin, and V. I. Musikhin (*Trudy Inst. Met.*, 1958, (4), 9–13) The concentration of the galvanic element has been investigated and the role of the solid electrolyte in which fused quartz plays a part. The elements give results which are readily reproducible and may be used for measuring the activity of the elements dissolved in iron. It has thus been established that additions of Mn have practically no influence on the activity of Si in Fe–C–Si alloy but that additions of phosphorus decrease it.

Determining the activity of silicon in liquid iron under varying compositions and pressures of the gaseous phase V. I. Musikhin, O. A. Esin, and B. M. Lepinskikh (*Trudy Inst. Met.*, 1958, (4), 5–7) The effect of a reduction in the pressure of hydrogen and nitrogen in liquid iron on the activity of nitrogen has been investigated by means of the emf. The findings show that the activity of Si decreased with a reduction in the pressure of these gases according to a definite relation.

Concerning a certain false theory. (Criticism of articles by Dr W. Kuczewski) V. M. Szczedrin (*Hutnik*, 1958, **25,** (10), 377–385) A series of articles has appeared in the Polish press between 1950 and 1958 on the method of calculation of the equilibrium constant of metallurgical reactions. Although the existing method was satisfactory, a new method is propounded which conflicts with available data. The theory is now examined in detail, and using the reaction $2Fe+O_2=SFeO$ as an example it is concluded that its falseness arises from: (1) ignorance of experimental data relating to the temp. of the phase changes; (2, 3) the adoption of the same integration constants for the reactions between the substances; (4) incorrect transition from the change in the isothermal potential to the equilibrium constant expressed by means of the partial pressures of the gaseous components, as a result of which the dissociation of oxides appeared to be dependent on the density of the gaseous phase.—M.T.

Investigation of thermodynamical properties of the binary system iron-manganese in the solid state A. P. Lyubimov, A. A. Granovskaya, and L. E. Berenshtein (*Zhur. Fiz. Khim.*, 1958, **32,** (7), 1591–1596) A method is described for determining the partial vapour pressures of binary system components by surface evaporation. The curve for components with high vapour pressures is very steep at low concentrations and has a small slope for the remaining section. This means that on the graph, the regions corresponding to an average and to high concentrations of the more volatile components will be greatly compressed and represented by a very small section of the curve, so that a determination from readings of the graph would give rise to large errors; hence with large vapour pressure differences between components of binary sustems the method is applicable only for very small concentrations. With this method a study has been carried out of the Fe–Mn system in the solid state at 1213°, 1363°, and 1447° with a molar concentration of Mn varying between 0·0004 and 0·506. The metal ratio in the vapour phase was determined by spectrographic analysis.

Thermodynamics of mixtures of ferrous sulphide and oxide E. W. Dewing and F. D. Richardson (*JISI*, 1960, **194,** April, 446–450) [This issue].

Bandsaws speed testing of alloy steel plates E. A. Berry (*Steel*, 1959, **145,** July 20, 100) Test samples from thick steel plates are prepared by the following steps: a block is flame-cut; these are cut almost to size using special bandsaws; samples are hand machined to within $\frac{1}{32}$ in. of size: one pass on milling machine.—D.L.C.P.

An apparatus for conducting tensile tests at

moderately elevated and sub-zero temperatures F. J. Anders, M. W. Toaz, and E. J. Ripling (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 127–138) The development is described of a new type of tensile testing equipment ensuring axial loading, operating over a wide, continuous temperature range with automatic control, and with automatic data recording.

Modern installation for testing of large assemblies under static and fatigue loading B. Thürlimann and W. J. Eney (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 81–96) A description is given of the design and operation of a large testing machine installed at the Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. Loads up to 110000 each of two hydraulic jacks at rates of 250 or 500 cpm can be applied. Some tests made with the installation are described, and additional alternating stress and high-speed fatigue testing machines in the laboratory are described.

The temperature dependence of the yield stress in iron N. Louat, J. S. Erickson, and J. R. Low jun. (*Acta Met.*, 1959, **7,** Jan., 57–58) A letter. In connexion with a paper by Erickson and Low (*ibid.*, 1957, **5,** 405) in which it was suggested that the observed flattening of the yield-stress *v.* temperature curve for iron at low temperatures may be due to the occurrence of twinning rather than to the effect of atmospheric density taken into account by Louat (*Proc. Phys. Soc.*, 1956, **69,** 454) the author brings forward arguments to show that Erickson and Lows' suggestion is not necessarily incompatible with the author's modified theory of Cottrell locking. In reply (pp.58–59) Erickson and Low disagree that deformation is initiated by twinning in the temperature range 140°K to 78°K; in this range a Luder's band appears but necking and fracture appear within the band only before the latter spreads over the whole of the gauge length. If this partially deformed specimen is examined, twins appear only in the band, although the whole gauge length was stressed to the upper yield limit.

On the effect of static and dynamic preloads on the stress–strain curve for a low carbon steel R. C. Smith and I. Vigness (*Acta Met.*, 1959, **7,** March, 223–224) A letter. Experiments are described to show that the upper yield point, which disappears in a low-C steel by the first cycle of loading beyond the yield stress, does not do so if the subsequent stress–strain curve is obtained at a much higher strain rate than the first cycle of loading.

Meter-relay control system predetermines yield-point of metals (*Machine Design*, 1959, **31,** April 16, 156–157) A control system for stretch-forming giving yield points of the metals used is briefly described.

Transducers for strain measurement in intense radiation fields R. C. Smith and N. J. Rendler (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 73–80) Experiments directed towards the design of transducers suitable for accurate strain determination in the presence of γ- and neutron radiation showed that foil transducers bonded to metal specimens with ceramic cements operate satisfactorily for limited integrated neutron fluxes.

Calculation of the tensile strength of patented and cold-drawn steel wires L. Mankher (*Acta Techn.*, 1958, **22,** (3–4) ,265–283) [In German] Tensile strength after patenting and the increase of strength during drawing were determined by calculation and by means of nomograms. The advantages of the two methods are compared, and some examples worked out (22 refs).

Determination of ultimate tensile strength of steel St 37 I. Koranyi (*Acta Techn.*, 1959, **26,** (1–2), 135–151) [In German] A complete series of tests for the strength of steel girders for railway bridge construction is treated statistically with corrections for various factors. The modulus of elasticity is also found.

Investigation of the influence of additions to austenitic steels on the elastic limit at room temperature H. Nohl, B. Lux, and W. Siegfried (*Rev. Mét.*, 1959, **56,** June, 19–29) The alloys investigated contained 20%Ni, 20%Cr, 12%W and 2·5%Fe, and 10%Ni, 23%Cr, 58%Co, 6%Mo, and 1%Fe respectively, and the influence of additions of small amounts of Nb, Al, Ti, Ti+Al, Co, Cu, B, Cu+B, Mn, and Cu+Mn+Al on the elastic limit of these alloys is investigated in the as-cast and aged condition (11 refs).

An evaluation of the stress–strain properties of flake graphite cast iron in tension and compression G. N. J. Gilbert (*BCIRA J. Res. Dev.*, 1959, **7,** Aug., 745–789) Void formation in flake graphite cast irons, and its effect on the stress–strain properties of these irons, are considered. It is shown that, in tension, the effect of void formation is to prevent the recoverable strain curve from following Hooke's Law. No permanent damage is caused by void formation while the voids are associated with graphite flakes. At relatively high stresses, however, cracking in the matrix causes failure. It is shown that, in compression, the strains are relatively unaffected by void formation, and the recoverable strain curve is an approximately straight line.

On the statistical theory of tensile stresses in metals B. M. Strunin (*Doklady AN*, 1959, **125,** (4), 790–793) A mathematical model is proposed which makes it possible to analyse the behaviour of actual materials under any loads when the stress state is linear (i.e. to calculate the probability of one or another state and to determine the proportion of the elements in a given volume).

Newtonian theory of axial elasticity A. N. Procter (*Engineering*, 1959, **187,** June 19, 798–800) Compression tests are discussed and modes of fracture in iron and other materials are shown.

The dimensional stability of a precision ball bearing material E. B. Mikus, T. J. Hughel, J. M. Gerty, and A. C. Knudsen (*ASM preprint* 154, 1959, pp.9) Four structures of 52100 steel with 0–15% retained austenite were tested from −30 to +165°F at stresses up to 20000 psi and both stress and temp. were shown to influence the dimensions. The presence of >1·5% austenite produced instability, highly stable structures were obtained by removing all austenite either by high temperature tempering or by austempering.

Improved bend tester aids ductility study (*Steel*, 1959, **145,** July 6, 80) A new bend testing machine is described; designed specifically for Ti under temperature it is useful for other metals at room temperature. A sample is bent while under observation through a microscope so that the start of hairline cracking can be observed; ductility can then be measured in terms of critical bend radius.—D.L.C.P.

A theoretical study of plastic bending of sheets: Part I N. Alberti (*Ing. Mecc.*, 1959, **8,** Oct., 17–24) The object of this study is to determine the thickness variation occurring in sheet during plastic bending by examining the distribution of tension. Experiments show that thickness is reduced during bending. Part I deals with tension distribution and shows that the position of the neutral stratum depends on the geometrical elements as well as on the mechanical characteristics of the metal.

Development of a triaxial stress testing machine and triaxial stress experiments L. W. Hu (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 27–38) The development of a new triaxial stress testing machine of the hydrostatic pressure type is described, and tests carried out with it are reported. These are of four types—tubular triaxial tests up to 300000 lb/sq.in., two-load tension tests under pressure, double shear test under pressure, and cone indentation test under pressure (13 refs).

The failure of tubes under combined external pressure and axial load W. Stuiver and P. F. Tomalin (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 39–48) In the experiments described the relationship between external pressure and axial load at failure was examined for tubes which fail by plastic buckling under external pressure alone. It was found that collapse pressures were reduced by axial tensile loads, and external pressure diminished the axial tensile load which caused failure. The significance of the results is discussed.

The case for Charpy impact tests J. G. Olivieri (*Mach. Design*, 1959, **31,** June 25, 135–136) The impact test is a more reliable index of performance than is the tensile test for some purposes. Its value for projectiles is shown.

Influence of some metallurgical factors on the results of impact testing Y. Morillon. D. Lajeunesse, J. Plateau, J. Cordier, and R. Borione (*Rev. Mét.*, 1959, **56,** Nov., 595–608) This is the completion of an investigation on impact tests published earlier (1956, **53,** 426) Tests to show the effect of C content on impact strength have been carried out by decarburizing or recarburizing impact specimens of basic Bessemer steel, OH steel, and a pearlite-free Swedish steel. A statistical evaluation of the effect of N, Mn, and P contents, final rolling temperature, and rate of cooling after austenization is reported; and it is concluded that the effects of these factors can be explained mainly in terms of their action on the morphology of the carbides.

Results of impact tests on grey iron: 'Impact Modulus' A. de Sy, and F. Deknock (*Fond. Belge*, 1959, **29,** Oct., 229–233) Detailed results are given of impact tests on four groups of grey iron, classes 15–40, carried out by the Working Group Panel of Internat. Commission on Methods of Testing Cast Iron; they are described statistically and compared for average value against tensile tests, and the concept of 'impact modulus' is introduced.—S.H.–S.

Short-time impulses produced by longitudinal impact D. M. Cunningham and W. Goldsmith (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 153–162) Pulses generated in narrow rectangular bars of steel and Al by the longitudinal impact of a $\frac{1}{4}$-in. diameter steel ball were measured by resistance-wire strain-gauges and sandwiched piezoelectric quartz crystals, and compared with change of momentum of ball and bar. Results using strain gauges and crystals were similar, but the former are more convenient and of more nearly universal application.

Effect of deoxidation and inoculation on the purity and impact strength of converter rail steel D. I. Turkenich, S. T. Rostovtsev, V. I. Baptismanskii, and K. S. Prosvirin (*Chern. Metallurg*, 1959, (3), 21–25) By deoxidizing Bessemer rail steel with Ca–Si without Al an appreciable reduction of non-metallic inclusions is attained but impact strength is reduced. By deoxidizing with Mg–Si the non-metallic inclusions and the impact strength are higher than in the normal melts. Additions of small amounts of B, while not changing the quantity of the non-metallic inclusions, increases impact strength by 40–50% at temperatures below and above zero.

Automatic impact testing to 8°K T. S. DeSisto (*WAL–TR*–112/93; *PB* 140262, 1958, July, pp.25) AISI 4340 steel was included.

The effect of a brittle case on the notched impact transition of unirradiated and irradiated steel D. Hull and I. L. Mogford (*J. Brit. Nuclear Energy Conf.*, 1959, **4,** July, 230–233) Notched impact specimens of En2 steel with a brittle nitrided surface layer were irradiated with 8×10^{17} neutrons/cm^2 and the ratio of energy absorbed in fracture to that required to form a fast running crack was determined and the energy required for propagations. The transition temp. is very sharp and is raised on irradiation.

Charpy-V transition temperatures of ferritic iron alloys. Part I. Iron–oxygen and iron–aluminium J. E. Srawley (*NRL Rep.* 5290; *PB* 151555, 1959, April, pp.19) The transition temp. increased steadily with O_2 content/and was higher if furnace cooled from 1650°F after cold working than if oil-quenched. Fracture was intergranular below the transition temp. for annealed irons with 0·0039%O_2 or more and transgranular for quenched irons containing 0·0206%O_2 or less. In Fe–Al alloys it was always transgranular and transitions temp. and hardnesses were higher in the quenched than in the annealed condition.

Comparison of methods of determining stress concentration factor J. D. Lubahn (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 139–144) Measurements of stress concentration factors are reported using wire-resistance strain gauges are compared with results determined analytically and by photoelastic methods, using a V-notch Charpy specimen. It is concluded that values obtained by different methods vary by ~10%, particularly for geometries not representing plane stress.

Normalization procedures for NRL drop-weight test P. P. Puzak and A. J. Babeck (*Welding J.*, 1959, **38,** May, 209s–218s) Procedures are described to ensure standard test conditions in the NRL drop-weight test, in which a given steel is required to exhibit a small amount of plastic deformation in the presence of a cleavage crack. Test conditions have been correlated satisfactorily with service failures.

Impact testing and its use in quality evaluation in boiler-plates K. Kucia, M. Kurek, and S. Kwiatkowski (*Hutnik*, 1959, **26,** (7–8), 296–301) The authors describe the types of faults found in plates and their causes. They suggest several methods of heat treatment to reduce the change of failure. The effect of surface finish on the mechanical properties of the plates is considered. The authors also describe the results of investigations into surface finish during welding and give their conclusions under nine headings.

Examining large pieces of forged steel R. M. O. Weinbaum (*Bol ABM*, 1959, **15,** July, 567–571) The value of current methods of testing is criticized, and other tests, principally impact, are suggested, as giving better quality control.—S.R.-S.

Some metallurgical points of view on steels for welded structures E. Braaten (*Tekn. Ukeblad*, 1959, **106,** April 16, 325–330, April 23, 359–362) Influence of temperature on impact strength, and the effects of composition, stress system, and rate of loading are discussed.

A method of assessing the tendency of materials to cracks during impact bending B. A. Drozdovskii and B. Ya. Fridman (*Zavods Lab.*, 1959, (3), 320–328) Increase in the width of specimens, provided with notches, transition to impact testing, and reducing temperatures contribute to increasing sensitivity to tests for certain brittle conditions (temper-brittleness etc.). The specimens should have cross-sections as suggested by Mesnage, be provided with notches and subjected to cyclic loading during tests produced by a resonance oscillator. The notches may be of varying shapes. It has been shown that impact testing of such specimens is much more sensitive for revealing brittleness in steel than is impact testing on the usual specimens.

Effect of chemical composition and residual work hardening on the strength of hot-rolled sheet steel I. D. Kuzema (*Chern. Metallurg*, 1959, (3), 85–92) A method is described for determining the expected strength of sheet steel in the rolled condition and after normalizing, in relation to its chemical composition, by means of which it is possible to calculate at once the UTS with the help of numerical tables giving data for the influence of different elements. It is thus possible to determine at once the types of steel suitable for rolling. The expected UTS so calculated is a more reliable index for steel melters than the usual method of summation of the alloy elements.

Effect of work hardening on mechanical properties I. V. Kudryavtsev, T. V. Naumova, and L. M. Rozenman (*Metallov. Obra. Met.*, 1958, (3), 2–6) Appreciable deformation, 65 and 120%, greatly increases hardness, yield strength, and tensile strength of carbon steels and reduces slightly the ductile properties, relative elongation, and reduction of area. Plastic deformation lowers impact strength in steels St.3 and 45 at all temperatures up to 600°. Fatigue strength increases with increasing deformation in unnotched and remains unchanged in notched specimens. Subsequent heating, after hardening, at 300° further increases hardness and reduces impact strength Heating to 800° eliminates completely changes in mechanical properties due to plastic deformation.

Development of the structure of steel under the effect of hot plastic deformation C. Rossard and P. Blain (*Rev. Mét.*, 1959, **56,** Aug., 285–300) The transitory period, shown in the stress–strain curves is associated with a change of structure. It is shown that initial structure develop towards a definite grain size which, for a given steel, is a function only of the temperature and rate of deformation. For temperatures outside the transformation range, grain size is less for lower temperatures, at a given rate of deformation. The effects of annealing, temperature, and rate of deformation, and holding at temperature on recrystallization phenomena are examined. (10 refs).

Electron-microscopical observation related to the work-hardening of high-manganese steels Z. Nishiyama, K. Shimizu, and M. Oka (*Nippon Kinzoku*, 1958, **22,** Oct., 532–536) Samples cold-worked at room temp. that revealed strain markings were examined. The markings were grooves of triangular section composed of two planes, the intersection forming a sharp line. The line was assumed to be a trace of a thin platelet of ϵ-phase, the presence of which causes work-hardening.—K.E.J.

Observation of sonic waves originating during the plastic deformation of metals, in relation to the problem of brittle fracture in mild steel J.-B. Lean, and J. Plateau (*Rec. Mét.*, 1959, **7,** June, 91–99) Examination of the sonic waves set up in mild steel (0·04%C basic Bessemer rimming steel) showed that in the more severe trials, brittle fracture was preceded by the formation of Piobert bands. The mechanism of the Portevin Le Chatelier phenomenon was also examined by measuring sonic waves produced during tensile tests.

Tips on designing with residual stresses G. M. Sinclair, J.-D. Morrow, and A. S. Ross (*SAEJ*, 1959, **67,** Sept., 76–77) Fatigue limit and fatigue life and their effects in design are discussed for hard and soft materials.

Stress induced ordering and strain-ageing in low-carbon steels D. V. Wilson, B. Russell, and J. D. Eshelby (*Acta Met.*, 1959, **7,** Sept., 628–631) The increase of yield stress during strain-ageing develops too rapidly to be explained by long range diffusion of C and N to dislocations. It appears to be due to local ordering of interstitial atoms and seems to be proportional to the amount of dissolved solute. The effect is small in slowly cooled steels. Tests at −12°C and on quenched specimens at ordinary temperature give results in agreement with this mechanism.

Changes occurring in the surfaces of mild-steel specimens during fatigue stressing G. F. Modlen and G. C. Smith (*JISI*, 1960, **194,** April, 459–464) [This issue].

The mechanism of thermal fatigue H. S. Avery (*Met. Progress*, 1959, **76,** Aug., 67–70) The causes of thermal fatigue, or 'fire cracking', are discussed, and it is shown to be due to plastic flow induced by expansion and contraction during heating and cooling. Methods of examining the effect are discussed.

Monographs on fatigue fracture (*Soud. Techn. Connexes*, 1959, **13,** May–June, 215–230) Reports are given on seven service failures of various types due to fatigue.

Alternating compression fatigue tests on various types of tubular joints on a pressure vessel P. H. R. Lane (*Soud. Techn. Connexes*, 1959, **13,** May–June, 197–202) Tests on four types of welded joint are described and the results discussed.

Fatigue tests performed on high-temperature alloys in the temperature range 800–1000°C M. Hempel (*Stahl Eisen*, 1959, **79,** Oct. 15, 1501–1505) The fatigue behaviour of notched and unnotched test pieces of high-temperature alloys in the range 800–1000°C is reviewed from published information. The author summarizes the results obtained by other workers and discusses them (27 refs).—T.G.

Conditioning and overstressing effects on steel in fatigue tests carried out under increasing and decreasing load A. Ferro and U. P. Rossetti (*Met. Ital.*, 1959, **51,** Sept., 393–398) The fatigue tests are carried out on Cr–Ni steel of resistance 95 kg/mm.² The results are compared with those obtained under the conventional constant stress tests—calculating for each test the cumulative damage and fatigue limit. The results in general confirm the validity of the hypothesis of cumulative damage.

Fatigue tests under progressively reduced load U. Rossetti (*Met. Ital.*, 1959, **51,** June, 235–239) A device is described which can be fitted to the Prot machine for rotary bending stress designed to test fatigue under progressively reduced stress starting from a stress point above the fatigue limit. The first results are given of preliminary research on the effects of overload and relaxation.

On the practice of 'Progressive action' testing L. Locati (*Met. Ital.*, 1959, **51,** May, 179–184) The practice of speeding up fatigue tests is becoming standard. This method consists of increasing the temperature, load or rate, etc., whichever applies in any particular case, during the test itself. A substantial speeding up of the test is achieved with an appreciable saving in costs and time. It has been applied successfully to fatigue, creap wear, and workability tests and is thought capable of extension to other fields.

The influence of the micrographic structure on the fatigue resistance of spheroidal cast iron drive shafts D. Fortino (*Fonderia Ital.*, 1959, **8,** Jan., 3–8) This is a study of the degree of spheroidization of the graphite in iron treated with Ni–Mg alloy used for the production of driving shafts and the effect on the tensile strength, in particular the fatigue resistance of the driving shafts themselves. It is shown that the formation of graphite increases the fatigue characteristics compared with grey iron with normal lamellar graphite. These and many other examples show that the static characteristics increase to a greater extent than the fatigue characteristics.

The resistance of roller bearings under progressively increased load D. Senigalliesi (*Ing. Mecc.*, 1959, **8,** June, 7–12) The conventional method of carrying out fatigue tests had hitherto been to subject the roller bearings to constant load and velocity. This method produces wide variation in results, consequently a large number of tests was required and interpretation of results was uncertain. The method described consists of subjecting the roller bearings to progressively increasing load. The results using the new method are much more constant, the variation in many cases being from 1–5 compared with 1–50 using the conventional test, and a substantial reduction in the number of tests required is made possible.

Fatigue failures in ore bridges a review H. C. Prince (*Iron Steel Eng.*, 1959, **36,** July, 80–88) The results of an investigation, reviewed and illustrated in this paper, show that fatigue failures occurred repeatedly in stress-raised areas. Methods of counteracting this effect are described.

Techniques for creep testing at high temperatures D. J. Armstrong, D. Murray, and L. M. T. Hopkin (*J. Less-Common Met.*, 1959, **1,** April, 125–131) Specimens, creep adaptors, and furnaces are described and the creep curve for a cermet is shown.

A test for creep rupture under multiaxial stress I. Finnie (*Proc. Soc. Exper. Stress Anal.*, 1959, **16,** (2), 49–54) The problems involved are discussed, and a description is given of a tester designed for rupture and creep strain studies under multi-axial stress, by means of which tubes may be tested by combinations of tension, compression, torsion, and internal pressure at temperatures up to 500°F.

Development of apparatus and methods for measurement of creep to temperature of 3500°F M. J. Sinnott and W. R. Kressel (*NEPA*-1560; *AD* 156204; *PB* 139935, 1950, Aug. 15, pp.193) An extensometer system is shown with furnace designs. Measuring systems for high temp. using Geiger tubes or photoelectron multiplier tubes are also developed.

Investigating creep in the iron chromium–nickel austenitic alloys with titanium, niobium and tungsten additions M. G. Gaidukov and V. A. Pavlov (*Trudy Inst. Fiz. Met.*, 1958, (19), 140–148) The alloying of Kh20 N20 alloy with very small amounts of Ti, Nb, and W increases heat resistance under low loads of the order of 4–6 kg/mm². Creep in these alloys at relatively high temp. under low initial stresses occurs chiefly because of deformation along grain boundaries. Experimental findings confirm, however, that a number of alloy elements concentrates preferentially along boundary zones between crystals. Such a selective arrangement of these alloy elements strengthens the grain boundaries and increases heat resistance.

An investigation of the relationship between microstructure and creep-rupture properties of heat-resistant alloys A. P. Coldren and J. W. Freeman (*WADC Techn. Rep.* 58–204; *ASTIA Document* 155711; *PB* 151421, 1958, July, pp.63) Investigations are described into the relationship between properties at high tem-

peratures and condition of working, using Ni and A 286 alloy (1·35%Mn, 14·6%Cr, 25·3%Ni 1·4%Mo, 0·2%V, and 2·0%Ti), which is a ferrous alloy known to possess wide variability in properties which appear to be due to variation in prior hot-working conditions. In the case of A 286, the major factor appears to be the temperature of heating prior to working, rather than degree of working or finishing temperature (13 refs).

Creep stresses and strains in an axially loaded plate with a hole J. Marin (*J. Franklin Inst.*, 1959, **268,** July, 53–60) An approximate theory is given.

The effect of irradiation on creep M. L. Rudee (*J. Am. Soc. Naval Eng.*, 1959, **71,** Aug., 453–456) A type 347 stainless steel is included.

Apparatus for creep testing at room temperature S. Bergh, Å. Josefsson, and G. Lagerberg (*Jerkonts. Ann.*, 1959, **143,** (10), 694–697) The construction and operating principles of the equipment are described.

The technique of hardness testing V. L. James (*Sheet Met. Ind.*, 1959, **36,** Oct., 639–646) This first part deals with methods of hardness testing and test conditions. Dynamic and static tests, scratch tests, care and siting of testing machines, and measurement of the indentation are some of the subjects dealt with, the tests are made on copper.

Test blocks for indentation hardness testing J. G. Wood (*Machinery*, 1959, **95,** Sept. 9, 487–491; *Engineer*, 1959, **208,** Aug. 28, 147–149) The preparation of standards by the Nat. Physical Lab. is described. Hardness, uniformity, and depth of hardness are indicated.

The practical realization of the HV and HR scales of hardness R. S. Marriner (*Machinery*, 1959, **95,** Sept. 2, 405–410) Factors in the apparatus and its use leading to variability in the values obtained are discussed, and the methods of securing uniformity are indicated.

Relation between the hardness in the surface zones of hardened rail heads and the microstructure of the steel S. Hořejš (*Hutn. Listy*, 1959, **14,** (7), 649–656) The relation between structure and quenching practice in the surface zones of rail ends of 0·48–0·72%C steels was investigated metallographically.—P.F.

Fatigue fractures in machine components (*Tecn. Indust.*, 1959, **37,** June, 784–790) The characteristics of fatigue fractures and factors influencing fatigue are discussed.

The variation in hardness measured by the indentation produced by small loads and the electroplastic hardness (*Ing. Mecc.*, 1959, **8,** Oct., 31–40) After describing the various methods used for determining hardness the need for a general definition of hardness valid for measurement carried out by indentation produced by small, medium, or heavy loads becomes evident. The problem of the variation in hardness measured by the indentation produced by small loads is discussed and a series of experiments was carried out with a view to solving it. These consisted of measuring the elastoplastic indentation making the determination of thickness independent of the value of the load and the size of the indentation.

8 years' research work in the service of the German Office of Weights and Measures G. Krüger (*Neue Hütte*, 1959, **4,** Sept., 551–559) Research carried out on creep, brittle properties, and ultrasonic testing is reviewed.

Some observations on the ageing of low-carbon sheet steel E. R. Morgan (*SAE Trans.*, 1959, **67,** 34–38) A comprehensive theory of yield and ageing is advanced. The stages observed in ageing are described. Explanations of ageing are given in terms of dislocation theory and stress patterns in rolled sheet are considered. If the process depends upon the migration of C and N, the rate of migration, the time available for diffusion may be controlled. Either mechanical or chemical processes of control might be used.

Effect of ageing on precipitation in temper-rolled deep drawing steel sheet P. Fukne jun. and W. Lueg (*Stahl Eisen*, 1959, **79,** Oct. 1, 1398–1411) Condensed from a thesis by the first author. The ageing behaviour of a low-carbon deep-drawing steel was measured by electrical resistance changes and interpreted as precipitation or phase separation by the Cottrell mechanism of dislocation cluster formation. The experiments show that a combined ageing process must be assumed in temper-rolled samples, the ratio of work-hardening to age-hardening depends mainly on the degree of inhomogeneity which is defined. It is recommended to use rolls of very small diameter for temper rolling and many passes at a low, total reduction. The report is followed by a very interesting and lengthy discussion (27 refs).—T.G.

Brittle and ductile fracture in metals F. de Kazinczy (*Jernkonts. Ann.*, 1959, **143,** (10), 617–645) Recent developments in fracture theory are reviewed. Some models for brittle nucleation are described. Local stresses surrounding the nucleus are taken into account, and treatments are generally modified to fit concepts of dislocation theory. Fracture at low temperatures of plane and notched tensile bars is described in detail, and the results discussed in relation to ductile-brittle transition, relationship between grain size and critical normal stress, and the nucleation process in fibrous fracture (48 refs).

Brittle failure of metals V. I. Sarrak (*Uspekhi Fiz. Nauk*, 1959, **57,** (2), 339–361) A detailed study of the literature, mostly American and English, covering: theoretical strength of metals; Griffith's theory; dissociation theory of failure; yield-point, as a function of temperature; influence of impurities, structure and tendency to brittle failure, inter-grain fracture, and the spreading of cracks and fissures.

Embrittlement of a 12%Cr–4%Ni steel G. T. Brown and R. T. Allsop (*JISI*, 1960, **194,** April, 435–442) [This issue].

Embrittlement in steels G. T. Brown and R. T. Allsop (*Iron Steel*, 1959, **32,** July–Aug., 385–387) Measurement of embrittlement, and the structural mechanism by which embrittlement has been found to occur are discussed with reference to the literature (30 refs).

New possibilities of evaluating the liability of metals to embrittlement V. Koželev (*Hutn. Listy*, 1959, **14,** (5), 409–415) Notch impact values are unreliable for assessing the brittleness of metals at elevated temperatures. The possibility of using also the notch impact values obtained after cooling the metal to room temperature as an indication of their high temperature susceptibility to embrittlement is discussed.—P.F.

Comparison of the technique of brittle fracture tests (*Soud. Techn. Connexes*, 1959, **13,** May–June, 183–196) A report of sub-committee A of Committee IX. Several grades of steel were submitted to a number of types of brittle fracture tests. The results are reported, compared, and assessed.

Notch ductility of mild-steel weld metal F. Watkinson (*Brit. Weld. J.*, 1959, **6,** April, 162–174) The results are given and discussed on work carried out for BWRA with the aim of comparing the brittle fracture tendencies of various mild steel weld metals. Transition characteristics and tendency to micro-fissuring were investigated, and the results—Charpy V-notch impact data, tensile results, hardness surveys, and chemical results being tabulated, and some results of radiographic examination given. The micro-fissure survey confirmed that the basic-type electrode was best suited to give a fissure-free deposit.

Thoughts and considerations on the effect of temper brittleness C.-G. Nestler (*Technik*, 1959, **14,** Nov., 725–732) A review of the development of present theories of temper-brittleness is followed by the investigation of the initial and final brittle structure. Thin, solid separating walls consisting of very fine carbide particles were observed on the fractured surfaces of temper-brittle specimens, and these were related to the residual austenite and intermediate stage ferrite of the tempered structure. The metallographic technique used is described, and the results are discussed (65 refs).

Brittle fracture tests of steel plates containing residual compressive strain S. T. Rolfe, W. J. Hall, N. M. Newmark (*Weld. J.*, 1959, **38,** April, 169s–175s) Experiments in which a residual compressive strain field was produced in the central portion of a 2-ft wide steel plate showed that such a field affects the initiation and propagation speed of a brittle fracture. The results suggest the possibility of prestressing parts or the whole of structures to provide a barrier against fracture initiation.

Effect of residual stress on brittle fracture H. Kihara and K. Masubuchi (*Weld. J.*, 1959, **38,** April, 159s–168s) Experiments at various temperatures on specimens with a sharp transverse notch showed that residual welding stresses which have no effect on the ductile fracture of welded structures may have an essential influence on brittle fracture. The effect of preloading, and the use of stress-relieving heat-treatment and non-destructive testing are discussed.

Influence of the notch effect on the brittleness of mild steels P. E. Lagasse and F. Marquet (*Rev. Mét. Mém. Sci.*, 1959, **56,** Nov., 629–639) A series of tests on various structural steels, showed (a) the notch effect is different in mild and high-strength steels (b) impact tests with a sharp notch ($r \leq 0{\cdot}25$ mm) appear to be most suitable for routine testing of brittleness.

Influence of thermal treatment on the displacement of the brittle-ductile transition observed during impact tests and the cold working of certain steels J. Dedieu and R. Delannoy (*Rev. Mét. Mém. Sci.*, 1959, **56,** Nov., 567–581) It is shown by means of examples of a ferritic 17%Cr stainless steel, steels for use at low temperatures, a low-alloy low-C Ti-gearing steel, and steels susceptible to ageing, that the nature of the initial heat treatment and the rate have an important effect on the position of the brittle–ductile transition.

Resistance to brittle breakage of cracked steel plates (*Rev. Soud.*, 1959, **3,** 147–152) A review, following a similar study by the US Ship Structure Committee of methods of testing, with an illustration of a 600-t tensiometer and test results.—S.H.–S.

Influence of trace elements on the notch brittleness of low-alloy steels, hardened and tempered J. M. Capus (*Rev. Mét.*, 1959, **56,** Aug.–Sept., 181–189) It is shown that high-purity vacuum-melted Ni–Cr–Mo steels are not susceptible to '350°C brittleness' when tempered within the range 250–400°C. Investigation of the impact properties of Ni–Cr–Mo steels containing P, As, Sb, Sn, and Mn shows that each of these impurities can promote this type of embrittlement.

The effect of the structure of unalloyed carbon steel on hydrogen absorption, permeability and embrittlement F. Erdmann-Jesnitzer (*Neue Hütte*, 1959, **4,** Nov., 669–679) The effect of unalloyed carbon steel structure on H_2 permeability has been studied in a series of tests with various temper structures. The curves for H_2 permeability as a function of time show an increase in H_2 permeability with rising temper temperature. The results are incorporated in hydrogen-permeability temper temperature diagrams.—L.J.L.

Fracture tests on steel specimens after cathodic or chemical saturation J. Dedieu and L. Pennec (*Rev. Mét. Mém. Sci.*, 1959, **56,** Nov., 582–594) Steels for making high-strength tubes for the petroleum industry N80 quality normal, modified (Cr–Mn) or alloyed with Cr–Mo and V, and J55 quality (C–Mn) were saturated with H_2 and submitted to tensile tests. From the results of these tests a classification was made in terms of Bastien's index of brittleness. Composition and heat treatment were then related to conditions where H_2 embrittlement may be anticipated (14 refs).

The influence of the chemical composition and the operation of a melt of Hadfield steel in a basic electric arc furnace on its tendency to hot cracking G. Kniagimin and W. Longa (*Prz. Odlew.*, 1959, **9,** (7), 197–206) The effect of chemical composition (C, Si, Mn, P, S, and the Mn–C ratio) and quantity of Al addition on the above phenomenon and the tendency on the part of Hadfield steel to crack was investigated by means of modified F. Althof and R. Radtke tests.

Hot cracking of mild steel welds P. W. Jones (*Brit. Weld. J.*, 1959, **6,** June, 269–281) High temperature tests carried out *in vacuo* and in H_2 and N_2 atmospheres showed relatively low ductility at 950–1100°C, not appreciably affected by changes in the atmosphere. Little correlation was obtained between suscepti-

bility to hot cracking and minimum reduction in area in tests at about 1000°C, and none between susceptibility to hot cracking and temperature of rupture under a small dead load. After limited hot working, weld metal still shows a minimum, much less marked, at about 1000°C.

The influence of impurities on the development of hot cracking in deposited metal M. V. Pridantsev and A. S. Astav'ev (*Svarochnoe Proizv.*, 1959, **32,** (3), 18–22) Previous research has shown that in the presence, in austenitic steels, of low m.p. impurities (e.g. Pb) distributed along the grain boundaries, the plastic props at high temps. are sharply reduced, which leads to hot cracking during forging and rolling of ingots, and a reduction in the strength of the grain boundaries at high temperatures, with a consequent reduction in the long-term strength, impact strength, and plastic properties after short test periods. On the other hand the addition of alkalis and rare earth elements increases the strength of the grain boundaries. The research described was aimed to study the effect of additions of the following, 0·002–0·020%B, 0·02–0·20%Ce, 0·10–0·40%Ca, 0·002–0·020%Pb, 0·10–0·40%Ba, 0·002–0·020%Sn, and 0·06–0·050%S to melts of the following composition, 0·03–0·045%C, 1·3–1·48%Mn, 0·28–0·5%Si, 18·5–18·9%Cr, 18·0–18·5%Ni, 0·014–0·020%S, 0·015–0·020%P; from which the electrodes were prepared. Special care was taken to restrict the Pb, Sn, Sb, Bi, As, and Zn contents within limits untraceable by spectral analysis. The electrodes were used for submerged arc surfacing of steel of the following composition, 0·05%C, 1·67%Mn, 0·37%Si, 18·7%Cr, 9·06%Ni, 0·019%S, and 0·017%P. It was found that B increased the tendency to hot cracking <0·042%Ce and <0·4%Ca did not produce cracking, but the effect of <0·4%Ca was dependent on the flux; <0·4%Ba had no affect on the tendency to cracking; and <0·017%Pb, <0·0016%Sn, and increased S contents promote the process, so that electrodes should be particularly pure in respect of these elements.—M. T.

An investigation of hot cracking in low-alloy steel welds P. W. Jones (*Brit. Weld. J.*, 1959, **6,** June, 282–290) Effects of some alloying elements, C, Ni, Cu, Cr, and Al, preheating and weld size are examined (18 refs).

The phenomena of cracking and fracture of steel in the presence of hydrogen P. Bastien (*Arch. Hutn.*, 1959, **4,** (2), 93–121) [In French] A review with discussion of mechanisms (41 refs).

A study of the causes of crack formation in 18KhNVA and 12KhN3A chromium-nickel steels I. P. Zabaluev (*Stal'*, 1959, (9), 811) A note from Dneprospetsstal. Hot charged ingots cracked much more often than cold charged ingots and scrap was at a minimum with casts teemed in 160–200 sec and at a maximum in those teemed in 150–160 sec. Scrap was much reduced with delays of less than 2½ h between finish teeming and charging to soaking pits.

Cast-pin tear test for susceptibility to hot cracking F. C. Hull (*Weld. J.*, 1959, **38,** April, 176s–181s) A new test to evaluate the susceptibility of alloys to hot cracking (the CPT test) consists in levitation melting tapered pins in a series of Cu moulds, restraints at the ends of the pins improving tensile stresses. Detail of the tests and results are given.

Some recent experiments on the friction wear and deformation of solids F. P. Bowden (*SAE Trans.*, 1959, **67,** 650–658) Work at Cambridge on a large range of metals and other materials is reviewed.

Methods for abrasion testing of steel under impact-alternating loads S. S. Ermakov (*Zavods. Lab.*, 1959, (3), 337–339) Three types of steel were investigated on a special apparatus, a diagram of which is given. The specimens were previously carburized in solid carburizers at 930±10° for a depth of 1·5–1·7 mm and differently heat-treated so as to have several structures. Findings show that the resistance of these steels to abrasion depends little on their chemical composition but chiefly on the structure and hardness of the eroded layer.

Junction growth in metallic friction: the role of combined stresses and surface contamination D. Tabor (*Proc. Roy. Soc.*, 1959, **251A,** June 9, 378–393) The adhesion mechanism is further considered and increase of area of contact with tangential force is especially discussed. It is shown that while surface contamination means that the transmitted stresses cannot exceed the critical shear stress of the surface, growth of contact area is the same up to this limit as it is in clean metals. Gross sliding then occurs, and it is shown that with an interface only 5% weaker than the metal this happens when the coefficient of friction is ~1. This agrees with observations in presence of traces of O_2. In presence of lubricant, little growth takes place.

Some studies of wear and lubrication A. W. Crook (*Wear*, 1959, **2,** Aug., 364–393) The wear process has been examined by optical, electron-optical, tracer, and metallographic techniques and two distinct types are distinguished, a severe form due to metallic welding and a mild form where the debris is finely divided and mainly non-metallic. The process of line contact lubrication in gears and bearings has been partly elucidated.

Effect of phosphorus on the wear of iron castings V. B. Lyadskii (*Lit. Proizv.*, 1959, (8), 44) A confirmation of the views expressed by A. V. Portugeis in *Lit. Proizv.*, (2) of 1959, that P increases resistance to wear of high-strength irons with pearlitic structure, i.e. irons with spheroidal graphite.

Influence of phosphorus on the resistance to wear of irons S. S. Bogdanovskii (*Lit. Proizv.*, 1959, (8), 44–45) Another commentary on the article in *Lit. Proizv.*, 1959, (2), by Portugeis confirming that a good pearlitic structure with fine lamellar graphite ensures high mechanical properties and appreciably higher resistance to wear than a ferritic structure.

About corrugated rails E. Czitary (*Eisenbahntechnische Rundschau*, 1959, **8,** June, 247–258; from *Brit. Railways Monthly Rev. of Tech. Lit.*, 1959, Oct., 3) A possible mechanism for wear of this type is suggested.

The thermal radiation characteristics of solid materials. A review H. H. Blau jun., J. L. Miles, and L. E. Ashman (*AFCRC–TN–58–132; ASTIA Doc. AD* 146833; *PB* 131962, 1958, March, pp.86) A critical review of the literature (1900–1957), dealing with fundamental laws and definitions; the emissive and optical properties of materials and experimental techniques and results (244 refs).

Problems and outlook of non-destructive testing F. Günther (*Neue Hütte*, 1959, **4,** Sept., 559–562) Subjects dealt with are: coarse structure investigations using X-ray and gamma radiation; ultrasonic and other testing methods, and training of personnel.

Permanent magnet materials R. J. Fabian (*Mat. Design Eng.*, 1959, **50,** July, 108–114) A review of steels, Alnico alloys, other magnetic alloys, ceramics, and five particle magnets.

Coercivity of γ-Fe_2O_3 powders E. P. Wohlfarth (*J. Appl. Phys.*, 1959, **30,** Sept., 1465–1466) A letter.

On the nature of the change of the coercive force upon annealing of hardened low-carbon steel I. A. Bildzyukevich, Ya. M. Golovchiner, and G. V. Kurdyumov (*Problemy Metallovedeniya i Fiziki Metallov.* (Moscow 1955) *AEC–tr*–2924, 1957, 138–139) Factors affecting the process are the martensite transformation itself which forms characteristic micro- and submicro structures and stresses, the properties of the martensite crystals and the unavoidable heterogeneity in the hardened steel. X-ray and coercivity studies were made on a steel with 0·10–0·12%C quenched from 1100°C in water and tempered at 100, 150, 220, 270, 400, 450, and 600° in sequence and examined at each stage. The changes observed appear to be due to processes occurring inside the supersaturated α-solid solution of the martensite crystals and may be carbon distribution. Tempering at 220° reduced the coercive force produced by hardening to half, and this is due only to stress reduction and does not change structure on the positions of the Fe atoms. **On the changes of coercive force in low-temperature tempering** N. S. Fastov (148–150) A calculation is presented which agrees with measured values. **On the coercive force and the width of the X-ray interference line in low-carbon alloyed steels** Ya. M. Golovchiner and V. M. Golubkov (151–154) Cylindrical specimens with compositions 0·11%C, 1·48%Mn, 1·4%V, and 0·16%C, 1·16%Nb were examined for hardness, coercivity, and X-ray interference line width. The carbides present required 1320–1330° for hardening and heating was carried out *in vacuo* sealed in SiO_2 ampoules for 10 min, dropped into 10%NaOH solution and the ampoules crushed. This gave practically complete solid solution. Tempering was carried out at 100, 200, 300, 400, 450, 500, 550, 600, 650, and 700° successively with measurements between steps. The steel was found to remain homogeneous by carbide analysis as well as by the physical measurements. At the same time annealing at 500° caused a large fall in coercive force (25 to 13 Oersted and 18·5 to 10 Oersted) and an explanation is advanced in terms of relaxation of stresses of the second kind by carbon diffusion, the X-ray line width remaining unchanged. Hardness is affected by lattice distortion and coercive force by lattice stresses. **Thermodynamic activity of carbon in austenite containing manganese and silicon** V. M. Rozenberg and L. A. Shvartsman (211–218) An equation is proposed for austenite containing Mn and Si which gives approx. the solubility of C for various compositions at 1000°. Estimates of heat of solution of C at various Mn concentrations are made. **On the nature of the hardness of tempered steel** G. V. Kurdyumov (221–231) Explanations for the resistance to deformation of tempered steel are discussed. Volume changes with strain hardening, strong bonding within the crystals or large distortions due to carbon solution and dispersion hardening have all been suggested. Evidence so far has been that all these processes play some part but the importance of each has not been determined. X-ray studies were made and the fine structure intensively examined. The properties of the martensite crystals appear to be the most important factor but this and the other factors are considered in detail and suggestions for increasing the strength level are made. **X-Ray analysis of deformations and binding forces in the crystal lattice of metals and alloys** G. V. Kurdyumov, V. A. Ilyina, V. K. Kritskaya, and L. I. Lysak (232–245) Widths and intensities of X-ray interference fringes were measured and their significance is discussed and the various equations formulated. Fine structure, areas of coherent scattering, magnitude of elastic deformation, amplitude of thermal vibration and static disorder in the lattice can be elucidated and applied to the study of the strength of metals (28 refs). **Variation of the kinetics of weakening with the composition of the strengthening phase during dispersional hardening** G. V. Kurdyumov, R. I. Entin, and V. M. Rozenberg (246–256) The Fe–Ni–Cr system was studied in regard to carbide separation and coagulation during annealing which may lead to loss of strength but can be delayed by suitable treatment. Small amounts of Co in chromium carbide do not appreciably change time or temperature of dissolution. W increases the solution temperature to 1300–1350° (by a kinetic and not by a solubility factor). Nb increases the solution temperature of $Cr_{23}C_6$ and the partition of Nb between solid solution and NbC is a definite function. These solubility variations are related to the effects of ageing and the relation of the weakening effects to the composition of the precipitating phase is shown. **Energy of a deformed crystalline lattice** N. S. Fastov (257–264) X-ray findings of the structure of plastically deformed metals are considered and equations for calculation of residual stresses are developed. **Thermodynamics of crystal lattices with vacancies** N. S. Fastov (265–274) A mathematical investigation of vacancy effects is presented, equilibrium conditions being derived. **X-Ray determination of the characteristic temperature of chromium nickel and molybdenum** V. A. Ilyina and V. K. Kritskaya (275–276) Binding forces have been measured from the intensity of X-ray interferences by determining the thermal factor. The characteristic temperature is the root mean square amplitude of thermal vibrations. Plastic

deformation was shown to have no effect. These temperatures are: Ni 350°, Cr 580°, Mo 400°, and Fe 430°. **X-Ray investigation of interatomic reactions in solid solutions with a nickel base** G. V. Kurdyumov and N. T. Travina (277–280). **Effect of chromium on the binding forces in α-iron crystals** V. K. Kritskaya, G. V. Kurdyumov, and T. I. Stelletskaya (281–283) Characteristic temperature was measured from X-ray reflection intensities at two temperatures. Alloys with 2, 8, and 16%Cr were used after annealing 10 h at 1200°. **Binding forces and statistical deformations in the lattice of alloyed ferrite** V. A. Ilyina and V. K. Kritskaya (284–288) The effects on the forces between the iron atoms produced by up to 2%Mo, Nb, Mn, Co, and V were examined. Significant increases were produced by all but V, which weakens the interatomic forces and lowers the characteristic temperature. **Effect of alloying admixtures on the temperature dependence of the shear modulus of iron** N. S. Rysina and B. N. Finkelshtein (289–293) An iron with 0·03%C was studied over the range 20–800°C by the method of free torsional oscillations in apparatus shown and pure iron and alloys with 2%V, Mo, and Co and 1·5%Mn were used in the form of wires 0·7 mm dia., degree of reduction 88%. Specimens were annealed *in vacuo*, iron 100 min. at 680° and the alloys 1 h at 800° and cooled in the furnace. Iron and alloys with Co, V, and Mn shows a fall in shear modulus at 360° but Mo steel remains relatively high to 480°. Above 500° the modulus of pure Fe drops fastest and V has the greatest restraining action on the reduction at this temperature. **Investigation of the variation of intensity of X-ray interference lines of deformed steel** V. A. Ilyina and V. K. Kritskaya (294–298). **Determination of vapour tension of solid cobalt in iron using radioactive isotopes** Yu. V. Kornev and V. N. Golubkin (299–311) The method of measuring rate of escape of vapour from a small jet was used and this and other methods are discussed and the apparatus described. An expression for vapour tension between 1050–1250° is given and heat of sublimation is calculated (95·2 ± 0·8 kcal/g-atom). An expression for the temperature dependence of the vapour tension of γ-iron at 1191–1350° is also given and the heat of sublimation of iron as 103·5 ± 0·6. **Determination of binding energy in the austenite lattice** Yu. V. Kornev (312–316) Vapour tension and heat of sublimation were measured in apparatus described using ^{59}Fe as tracer. Carbon is shown substantially to reduce binding forces in austenite, 5·8% reducing the binding energy from 103·5 to 43·5 kcal/g-atom, and agreement with X-ray data was obtained. **Influence of carbon on the binding forces and on the static distortions in martensite crystals** G. V. Kurdyumov, V. K. Kritskaya, and N. M. Nodia (317–321) X-ray interference measurements at two temperatures (room and −185°C) on steels with 0·08, 0·1, 0·35, 0·84, and 1%C were made after quenching in 10%NaOH, and hardness was also measured. Although binding forces are reduced as compared with α-iron, the high elastic limit is apparently due to large static distortions caused by the dissolved carbon. **X-Ray analysis of the carbide phase of patented steel wire** V. M. Golubkov and V. K. Kritskaya (322–325) Wire with 0·8%C deformed by 25, 65, 75, and 95% and tempered at 400, 600, and 680° was used and the carbides were removed electrolytically. Block sizes after the various treatments are tabulated. Extreme dispersion of structural components is revealed. **On the diffusion of cobalt, chromium and tungsten in iron and steel** P. L. Gruzin (329–336) Temperature dependence of the diffusion coefficients of Co, Cr, and W in α- and γ-iron and in eutectic carbon steel was measured over the range 700–1250° using tracer methods. Calculated data are compared with the measurements. **On the problem of studying diffusion by the method of radioactive isotopes** P. L. Gruzin and D. F. Litvin (337–342) Theory is worked out and checked against measurements of ^{60}Co diffusion in iron over a range of temperature. Diffusion parameters were in good agreement for α-iron but much less so for γ-iron. **Influence of intra-grain structure of austenite on the self-diffusion of iron** P. L. Gruzin, E. V. Kuznetsov, and G. V. Kurdyumov (343–345) Effects on diffusion of the austenite–martensite transformation were examined and anomalous effects observed in diffusion in these temperature ranges are correlated with the surface diffusion effects at boundary interfaces. Fe–Ni–C alloys annealed 5 h at 1330°, some cooled in liquid N_2 to produce martensite, were used and measurements were made at 900, 950, 1000, and 1100° beyond the inverse transformation-point. The results were in accordance with the hypothesis. **Influence of carbon on the self-diffusion of iron in the system iron–nickel** P. L. Gruzin and E. V. Kuznestov (346–349) As an alloy was required in which C would form a solid solution and as the second element was preferably to be chosen to widen the range of the γ-phase the Fe–Ni system was chosen; eight alloys were used with from 19·65–25%Ni; these were homogenized at 1200° for 20–25 h in H_2, forged, and cut to 30 × 10 × 7 mm specimens. Five were martensitic and three austenitic after quenching, in two of the former much residual austenite remained. Diffusion was measured with ^{59}Fe. Carbon was found to weaken the bonding in the solid solution Fe–Ni and the effect decreased with increasing Ni. **Influence of manganese on the self-diffusion of iron** P. L. Gruzin, B. M. Noskov, and V. I. Shirokov (350–354) Increase of activation energy with Mn up to 4% was found for both volume and intercrystallite diffusion. Further increase to 8% decreases both diffusion rates. **Influence of alloying on the self-diffusion of cobalt** P. L. Gruzin and B. M. Noskov (355–360) Co–Fe and Co–Fe–Ti alloys were included in the study. **Influence of chromium on the self-diffusion of iron** P. L. Gruzin (362–364) Studies on 4% and 8%Cr steels show that atomic bonding is strengthened by the Cr in γ-iron and the mobility of Fe atoms is reduced. The carbon also appears to weaken interatomic forces in these alloys. **A study of the self-diffusion of α-iron** V. M. Golikov and V. T. Borisov (365–376) A method for determining small coefficients of diffusion is described taking account of both active layer and boundary surface processes. It is not necessary to measure β-absorption before starting as the absorption has a negligible influence on the method. Methods of taking into account isotopic composition and the characteristics of the counter are shown. The temperature coefficient was found for the range 650–850°C and the activation energy determined as 67 100 cal/mole. **Theory of methods for determining concentration dependences on diffusion coefficients in solid solutions** B. Ya. Lyubov and B. I. Maksimov (377–400). **On the plastic properties of modified steel Kh25N20 in the cast state** V. E. Neimark and Ya. B. Gurevich (439–449) Plastic properties in the hot state are improved by addition of Ti or B. Cast specimens with columnar structure has good plasticity at room temperature and can be cold-worked. Diffusion annealing for 1 h at 1250° improves plasticity at room temperature by cementing the dendritic structure. Nb, V, and Ti were used in the trials, Cr should be low to avoid separation of σ-phase. **On the deformability of cast steel of type Kh25N20** Ya. B. Gurevich and V. E. Neimark (450–455) Under defined conditions the steel with columnar macrostructure has adequately high ductility both cold and hot. The optimum rolling temperature is 1150°C. The cast metal requires annealing at 1250° to destroy sigma-phase and to remove strain and also water cooling to prevent carbide separation. Hot rolling can be carried out up to 60–65% reduction and, on small parts, to 75%. In lengthwise rolling with non-uniform deformation and in tube rolling reduction should not be greater than 45–50%. In some cases the steel can be cold-rolled with small reductions up to 50% without heat treatment so that direct rolling into tubes is possible. **Use of compensators to improve the distinguishability of defects in the photographic method of γ-ray flaw inspection** E. V. Borisov (470–472) Liquid compensators such as methylenediiodide in benzene or BaI_2 in water are recommended to give images of parts of greatly varying thickness within the range of density of the emulsions.

Magnetic materials H. Fahlenbrach (*Tech. Mitt. Krupp*, 1959, **17**, May, 95–99) Magnetic substances and their importance in communication techniques are discussed. Oxidized and metallic magnetic materials, isotropic and anisotropic substances are dealt with, and relationships between material properties and physical properties are reviewed (10 refs).

The magnetic properties of iron F. Luciani (*Fond. Ital.*, 1959, **8**, March, 105–106) An explanation with the aid of examples of the nature of magnetism in relation to the properties of iron.

Magnetic annealing effect in α-Fe_2O_3 T. Iwata, M. Iwata, and M. Yamamoto (*J. Phys. Soc. Japan*, 1959, **14**, June, 855–856) [In English].

Regarding control methods of the magnetic properties of electro-technical sheet iron R. I. Yanus (*Trudy Inst. Fiz. Met.*, 1958, (20), 141–151) A review of the methods and of the apparatus used with suggestions for improvements.

Magnetic control of the structure and mechanical properties of machine parts M. N. Mikheev (*Trudy Inst. Fiz. Met.*, 1958, (20), 163–168) A review of the position, with suggestions for some problems to be solved such as the elucidation of the relations between magnetic, electrical, and various other physical properties and the structure and mechanical properties of various instrument, structural, and special steels, on a wider use of magnetic analysis for studying the processes of ageing, self-ordering, and relaxation in paramagnetic austenitic steels.

Regarding the non-uniformity in sheets of the magnetic properties of cold-rolled electro-technical iron Yu. A. Vdovin and Yu. N. Yaroshenko (*Trudi Inst. Fiz. Met.*, 1959, (22), 137–142) Experiments have revealed a considerable non-uniformity in cold-rolled transformer iron within batches so that samples drawn at random may differ considerably from the average. It is suggested that an increased number of sheets per lot should be tested.

The influence of the original structure of transformer steels on their magnetic properties V. A. Koreleva, A. I. Mel'nikov, M. K. Bateneva, A. V. Serebrenikov, and T. S. Konovalova (*Stal'*, 1959, (10), 947–948) An investigation is reported on sheet 0·5 mm thick alloyed with Al and annealed for 24 h at 850–880°C. Sheet was rolled experimentally with two passes or five passes and microstructure was examined. An optimum annealing schedule for lowest specific losses and for avoiding brittleness is drawn up.

Rise of flux in solid iron core due to impact excitation N. Kesavamurthy and P. K. Rajagopalan (*Proc. Inst. Elect. Eng.*, 1959, **106C**, Sept., 189–192).

The significance of magnetic treatment at high temperatures on iron silicon alloys H.-D. Dietze (*Tech. Mitt. Krupp*, 1959, **17**, May, 67–81) The anomaly of initial permeability above 300°C in Fe–Si is explained by the diffusion of lattice vacancies in the block wall. The activation energy so obtained (3·3 eV) is in good agreement with that of self-diffusion in pure iron. Energy of formation and activation energy for the migration of the vacancies can also be determined. The influence of the vacancies on crystal energy is very great (20 refs).

The effect of hot deformation on the magnetic properties of austenitic steels M. M. Belenkova (*Trudy Inst. Fiz. Met.*, 1959, (22), 73–75) The method of determining magnetic susceptibility reduces itself to measuring the mechanical force acting on a specimen plane in a non-uniform magnetic field. Two types of steel were investigated: 60Kh3G8N8V and 40Kh3G18. Results of the investigations are given.

Geometric dependence of magnetic anisotrophy in thin iron films. Techn. Report No.3 T. G. Knorr and R. W. Hoffman (*AECU* 3877, 1958, Sept., pp.69; from *US Govt. Res. Rep.*, 1959, **32**, July 17, 140; no abstract).

The effect of high temperature tempering on the magnetic properties of magnetic alloys with small coercivity N. I. Lapkin and V. S. Mes'kin (*Izvest. A.N. Seriya Fiz.*, 1959, **23**, (3), 280–284) The investigations refer to Fe–Ni alloys; 50% Permalloy 50N and 50NKhS, to Mo in Permalloy N79M4 and also to cold-rolled dynamo steel. A comparison is made with hot-

rolled transformer steel. Findings for these different alloys are tabulated.

Investigation of structure of the new deformable magnetic alloys with large coercivity M. N. Raevskaya (*Izvest. A.N. Seriya Fiz.*, 1959, **23**, (3), 266–270) The components on the deformable magnetic alloys with large coercivity are at the present time classed into three groups. 1. The diffusion-hardening alloys of the system Fe–Ni–Al, and Fe–Co–Ni–Al. 2. Alloys with $\gamma \rightarrow \alpha$ transformations, among which are Fe–Co–V, Fe–Ni–Mn, and Fe–Cr–Ni. 3. Dispersion-hardening alloys of the Fe–Co–Mo, Fe–Co–W, or Fe–Co–Cr–Mo systems. The experiments described aimed at investigating structure and physical properties of some of these alloys. Explanations are offered for certain processes occurring in them.

Magnetothermal effects in iron and silicon-iron L. F. Bates and D. J. Sansom (*Proc. Phys. Soc.*, 1959, **74**, July 1, 53–64).

Magnetic viscosity in iron due to carbon atoms anchored in dislocations G. Biorci, A. Ferro, and G. Montalenti (*J. Appl. Phys.*, 1959, **30**, Nov., 1732–1735).

Deterioration of the magnetic properties ('spoiling') of tungsten magnet steel F-233, Part II J. Terraza Martorell and J. Ma. Bermudez de Castro y Mosquera (*Inst. Hierro Acero*, 1959, **12**, April–June, 122–135) The method of manufacture and composition of the cast from which the test specimens were made are given, and the test equipment described. The methods of examination–metallographic; radiographic and hardness testing are enumerated, and a table giving the heat treatment of the various specimens is presented.

Effect of neutron bombardment on the magnetic properties of iron G. Biorci and G. Bonfiglioli (*AFOSR TN–58–1096, AD 207597; PB 138781*, 1958, Sept., pp.49) Results confirm that the internal stresses produced are very small and that increased strength appears to be due to some mechanism of dislocation anchoring by point defects produced during irradiation.

Determining the content of the α-phase in austenitic welded joints by the magnetic method N. I. Kopersak (*Avtom. Svarka*, 1959, (1), 43–48) An empirical formula is proposed for assessing the magnetic saturation of the complex-alloyed ferrite taking into account the effect of the basic alloying elements. It is possible, by applying the formula to use the Armco-iron standards in all cases to determine quantitatively the α-phase in the austenitic metal of the welded joints by the magnetic method. This is based on the known fact that the different alloy elements in their normal concentrations in austenitic steels, lower linearly the magnetic saturation of iron.

Grain growth produced by slight deformation of rimming steel sheet. Its effect on magnetic properties V. Berruti and B. Sommacal (*Met. Ital.*, 1959, **51**, April, 129–138) The results are described of tests carried out on mild rimming steel sheet subjected to slight deformation followed by annealing. In particular the influence of the percentage of deformation, the temperature and time of annealing and the initial coarseness of the grain on the final grain size is examined. This is then related to the magnetic properties of the sheet. Finally the magnetic characteristics obtained by industrial process are described.

Effect of heat treatment on the flux density of hot-rolled transformer steel G. A. Zykov, M. I. Nekrasova, and V. V. Druzhnin (*Stal'*, 1959, (11), 1009–1012) Numerous laboratory studies were made and a heat-treatment schedule for maximum flux density is drawn up. Reannealing with slow cooling is advantageous.

The relation between the properties of cold-rolled transformer steel and the position of the zone in the ingot or on the hot-rolled coil from which it is derived A. I. Belyakov, M. S. Simakova, and A. A. Nefedov (*Stal'*, 1959 (11), 1016–1017) Sheets with the smallest specific losses came from the upper parts of the ingots or from the outer turns of the coils. The need for securing greater uniformity in decarburization is noted. To increase output of high quality metal testing of coils without cutting out samples should be developed.

Testing electrical sheet W. P. Crawley (*Elect. Times*, 1959, **136**, Oct. 15, 375–378) Equipment for measurement of magnetic properties is described.

Preferred orientation in silicon iron P. N. Richards (*J. Australian Inst. Met.*, 1959, **4**, Aug., 114–123) A 'Goss' type (110) [001] orientation develops in 3%Si iron during final annealing. Normal grain growth must be restrained for this to occur and finely dispersed Si_3N_4 may be the cause. Measurements by magnetometer and goniometer are described (18 refs).

Synthesis of a (110) [001] type torque curve in silicon iron C. G. Dunn and J. L. Walter (*J. Appl. Phys.*, 1959, **30**, July, 1067–1072) The curve is calculated from grain size and orientation.

Extraordinary Hall effect in silicon iron single crystals E. Tatsumoto and T. Okamoto (*J. Phys. Soc. Jap.*, 1959, **14**, July, 975–976) The extraordinary effect is found to be isotropic as in Fe single crystals. The coefficient at room temp. is $49{\cdot}2 \times 10^{-11}$ volt cm/Oe amp. A method eliminating the ordinary effect was used.

Eddy-current testing (*SS News*, 1959, June, 17–20) The theory and practice of eddy-current testing are outlined, and two examples of conductivity meters based on the use of eddy currents are given.

Eddy currents in solid iron due to alternating magnetic flux N. Kesavamurthy and P. K. Rajagopalan (*Proc. Inst. Elect. Eng.*, 1959, **106C**, Sept., 207–213).

Industry practices for eddy current testing of carbon, stainless and alloy steel tubular products (*AISI Contrib. Met. Steel*, 1959, July, pp.4).

The thermal and electrical conductivities of ductile cast iron and several grey cast irons J. H. Brophy and M. J. Sinnott (*ASM preprint* 139, 1959, Nov., pp.16) Effects of graphite size and distribution were examined. The lowest thermal and highest electrical conductivity occurred with spheroidal graphite. Thermal conductivity was a maximum with fully annealed iron with high C and low Si.

Tubing gets 100% inspection as eddy currents spot flaws (*Iron Age*, 1959, **184**, July 9, 89–91) An eddy-current method of flaw detection is described which meets ASTM specifications and provides continuous inspection of tubing.—A.G.

Progress in technology and equipment for eddy current inspection H. L. Garbarino and H. N. Nerwin (*Nondest. Test.*, 1959, **17**, July–Aug., 229–234) A general review of the principle of the method, the circuits and set-ups used and the sort of applications for which it is suitable with special reference to ferromagnetic materials.

Quality control with eddy current techniques C. E. Quinn (*Met. Progress*, 1959, **76**, Sept., 70–73) A description of the Laminagage, used for measuring the thickness of thin layers – for example the thickness of a plastic or other non-conducting layer on rolled steel, and for locating fine cracks.

On the superconductivity of iron films Yu. G. Mikhailov, E. I. Nikulin, N. M. Reinov, and A. P. Smirnov (*Zhur. Tekhn. Fiz.*, 1959, (7), 931–932) A special apparatus is described for vaporizing iron for various temperatures of deposition in thicknesses of 10^{-5} cm and below. Results show that freshly deposited films with slow speeds of vaporization of ~a few Å per min, immersed in liquid He, show superconductivity at 4·2 K. At higher temperatures the films revert to their normal condition. It was also found that films broke if over 10^{-5} cm thick.

Ultrasonic gauging faster, keeps specified tolerances (*Steel*, 1959, **145**, July 6, 81) An example of the use of a Vidigage, an ultrasonic thickness gauge is given. Accuracy is 0·1 to 1%.—D.L.C.P.

Investigations of specimens for the ultrasonic testing of chilled iron and roll iron J. Thieme (*Giesserei*, 1959, **46**, Sept. 24, 552–558) A discussion of the literature is followed by a description of ultrasonic tests to determine depth of chill in chill castings. It is shown that this value can be derived from the trace, and also that information concerning the Young's modulus and other physical properties can be determined from the tests.

Industrial applications of ultrasonics: recent progress J. Palmé (*Techn. Mod.*, 1959, **51**, May, 237–243) Improvements and developments in ultrasonic generators and methods of ultrasonic testing on the industrial scale in the past few years are reviewed, and the section concludes with a description of the ultrasonic microscope.

Specific applications of ultrasonic waves to non-destructive testing C. Bordoni (*Met. Ital.*, 1959, **51**, Aug., 324–332) After briefly outlining the main principles of non-destructive testing with ultrasonic waves a comparison is made between X-ray and ultrasonic methods showing the advantages of the latter. Some specific applications of ultrasonic waves are described such as testing the depth of fatigue cracks and structural defects by the absorption technique and examining the adhesion of antifriction metal to the bearing support.

The immersed ultrasonic inspection of metal plate R. W. McClung (*Nondestr. Test.*, 1959, **17**, Sept.–Oct., 270–275) Techniques are described for inspection of metal plate in thicknesses down to ¼ in. Possibilities of automation of inspection are discussed—a non-ferrous example is given.

Choice of the most favourable conditions in the ultrasonic testing of steel specimens J. Ors Martinez (*Inst. Hierro Acero*, 1959, **12**, April–June, 163–172) Some factors which can alter the oscillograms obtained in ultrasonic testing are discussed and compared, and working conditions are varied with the aim of establishing values which allow of the most accurate interpretation of the results obtained.

Ultrasonic detection of defects. General examination of factors affecting the significance of the results obtained by echo sounding B. R. Byrne (*Rev. Mét.*, 1959, **56**, July, 231–256) A review of factors causing energy losses is followed by a discussion of the signals emitted by defects and the reproducibility and assessment of the results obtained, with reference to the literature, and with particular emphasis on the examination of heavy forgings, slabs, and plates.

Practical applications of ultrasonics to the control of iron and steelworks products: possibilities and limitations L. Beaujard and V. Husarek (*Rev. Mét.*, 1959, **56**, July, 221–223) The limitations of manual inspection are pointed out, and methods of mechanizing some of these techniques, developed by IRSID, are described.

Ultrasonic weld testing made easier R. Hornung (*Engineering*, 1959, **188**, Sept. 4, 141–142) A report from Sulzer Bros. of testing equipment and of its use with rust-covered samples.

The absorption of ultrasonic waves in solids M. Redwood (*Rev. Mét.*, 1959, **56**, July, 172–180) The first part of this report consists of a discussion of the precautions necessary in using the multiple reflections of a short wave train between the two extremities of a specimen, for measuring the absorption of compression waves in solids of low damping capacity and at frequencies between 10 and 500 Mc/s. The second section surveys some of the methods reported for studying the effects of dislocation, internal friction, frequency, and temperature (49 refs).

The development of ultrasonic methods for materials testing in Poland L. Filipczynski and I. Malecki (*Nondestr. Test.*, 1959, **17**, Sept.–Oct., 276–280) Developments and research activities since 1955 are reviewed; the position at 1955 was outlined at the 1st International Conference on Non-destructive testing at Brussels in that year.

The value of standard blocks in non-destructive ultrasonic control M. Evrard (*Rev. Mét.*, 1959, **56**, July, 111–123) Comparative trials are described on two standard test blocks, one of British and the other of Dutch origin. Although both types gave satisfactory results for certain types of instrument, the Dutch standard was more versatile in its application.

Industrial applications of X-ray analysis S. Weissmann (*Proc. 7th Annual Conf.*, 1958, *Denver*, pp.359). **Substructure characteristics of fine grained metals and alloys disclosed by X-ray microscopy and diffraction analysis. I. Description and application of diffraction method** (21–37). **II. Description of X-ray double-crystal diffractometer combining X-ray**

microscopy and diffraction analysis S. Weissmann and K. A. Turner, jun. (37–45). **Selection of spectra for X-ray microscopy** I. I. Bessen (79–95). **Microstructure, mass and chemical analysis with 8 to 44 Angstrom X-radiation** B. L. Henke (117–155). **Further application of the intermediate X-ray probe** I. Adler, J. Axelrod, and J. J. R. Branco (167–173). **The evaluation of the PXQ [Production control X-ray quantometer] for the analysis of cements and related materials** G. Andermann, J. L. Jones, and E. Davidson (215–227) Analysis of ores is included. Mg, Al, Si, P, Ca, and Fe are determined. **A novel approach to discrimination in X-ray spectrographic analysis** P. Lublin (229–237) The use of an analysing crystal whose 2nd order reflexion is missing, such as Ge or Si cut parallel to (111), is described. **Crystal chemical studies by X-ray fluorescence** E. W. White, H. A. McKinstry, and T. F. Bates (239–245). **An application of the mutual standards concept to X-ray fluorescence spectroscopy: the analysis of meteoritic sulphide nodules for eight elements** A. A. Chodos and W. Nichiporuk (247–255) The analysis for Fe, As, Co, Cr, Cu, Ni, V, and Zn takes 20 min and the method is completely non-destructive. **Quantitative analysis of trace amounts of tin in steel by means of X-ray fluorescence** T. S. Whitehouse (257–260) As little as 0·01% was determinable with an accuracy of ±0·003%. **X-ray projection microradiography and divergent beam techniques** F. W. Von Batchelder (283–291) Cast irons and tool steel are shown. **A universal detector for the X-ray spectrograph** W. R. Kiley (293–301) A counter with nearly 100% efficiency over the whole range of λ used, including Mg, Kα radiation is described, and its use for cement analysis. **Recent developments in fluorescent X-ray spectrographic absorptiometric analyses of mineral systems** M. L. Salmon (303–312) The examples are mainly rare earths.

Influence of grain structure on ultrasonic attenuation in steel E. P. Papadakis (*J. Appl. Phys.*, 1959, **30,** Sept., 1463) Differences between bainite, martensite, austenite, and ferrite, of the same grain size are discussed.

Non-destructive testing in oil refineries G. Cibibin (*Met. Ital.*, 1959, **51,** Aug., 373–381) The prevention and study of corrosion by non-destructive testing in the chemical and petroleum industries are becoming increasingly important and widely used. This article describes the characteristics and uses of several instruments in frequent use in such tests. The description is completed by a series of examples which facilitate evaluation of the information obtained by different control instruments and enable comparisons to be made.

Results of studies undertaken by Commission V of I.I.S. on use of test blocks intended for control of ultrasonic examination gear. (Tests, measurement and control of welds) (*Rev. Soud.*, 1959, **15,** (3), 156–166) A comparative study of the possibilities offered by Dutch and British test blocks. Revised tests made at the annual assembly in Madrid 1956 by Belgian, Danish, French, and Swiss delegates are summarized. In appendices are given Dutch gauges, 2. British, 3. A note by W. W. Campbell on conclusions on tests. 4. A description of the system recommended by Comm. V. The Continental and British viewpoints differ.—S. H.–S.

The determination of material characteristics in iron–graphite-materials by ultrasonic methods H. Wiegand and H. Hentze (*Metall*, 1959, **13,** Dec., 1110–1113) The ultrasonic method described permits determination to be made of the graphite characteristics that are particularly important for the practical properties of iron–graphite materials.–L. J. L.

Contribution to the X-ray study of metals at elevated temperatures M. Čermák (*Hutn. Listy*, 1959, **14,** (7), 593–598) A new X-ray goniometer utilizing two Geiger–Müller counters is described, and examples of its utilization in the determination of S-curves of steels are given. The instrument, which is of Czechoslovak design, incorporates a vacuum furnace for heating the specimen, the latter being traversed by currents of up to 1000 A at potentials of about 2 V.—F. F.

New method for the determination of grain or crystallite size from spotty diffraction rings K. W. Andrews and W. Johnson (*Brit. J. Appl. Phys.*, 1959, **10,** July, 321–325) A method using transmission photographs in which the specimen is oscillated through a known angle is described.

The use of X-ray diffraction analysis in researches on phase equilibria F. Kupka (*Chem. Listy*, 1959, **53,** (8), 793–804) The scope of X-ray diffraction in this field is discussed with reference to existing methods and applications, including alloy systems. The Fe–Cr–Si system is included.—P. F.

Comparison of X-ray quality and tensile properties in cast high-strength steel H. R. Larson, H. W. Lloyd, and F. B. Herlihy (*Mod. Castings*, 1959, **36,** Nov., 676–684) Radiographs of thin sections cut from cast test-pieces of steel containing 0·4%C, 0·6%Ni, 0·85%Cr, 0·4%Mo showed that slight traces of porosity reduced the ductility.—A. D. H.

Industrial radiography apparatus and unified exposure on the basis of kV/mr curves A. Gilardoni and A. Taccani (*Met. Ital.*, 1959, **51,** Aug., 382–384) Starting from the dose necessary to make an exposure, a calibration and control method for industrial X-rays is described based on the dosimetric measure of the mr per min coming out of iron filters of a given thickness. The equipment and method employed for measuring are described and curves kV/versus mr/min are given. On the basis of the mr per min, the main characteristics of the X-ray generators, i.e. maximum radiographic efficiency, maximum specific radiographic efficiency and utilization cycle are examined. A standard exposition technique based on normalized kV/mr/mA curves is given.

Radiographic stress measurements with broad lines V. Wolfsteig (*Arch. Eisenh.*, 1959, **30,** July, 447–450) It is concluded that stress measurements on very broad diffraction lines, such as in hardened steel, should be carried out on forward scattering lines, and that the necessary increase in accuracy of angle measurement is possible with a counter goniometer. An example is given of the use of the technique on hardened gear wheels.

A new radiographic method for the control of corrosion A. Brioni and E. Magni (*Calore*, 1959, **30,** Aug., 418–422) A new method applying γ-rays to plain, T, and curved pipes, ½–24 in. dia., max. thickness 3–9 mm, without disturbing the working of plant or prior preparation is discussed with reference to experience over two years of Canadian Oil Co.—S. H.–S.

Investigation of the stress layer of 18/8 steel by means of electron diffraction Sh. Yamaguchi (*Werks. Corr.*, 1959, **10,** Aug., 499–501) Tests are described on a specially prepared specimen, using hard radiation of λ∼0·03 Å which identified the ferritic layer in an 18/8 steel and enabled the thickness of the layer to be measured.

First experiences with gamma radiography A. R. Hammond (*Machinery*, 1959, **95,** Aug. 19, 295–297) A brief review of sources, equipment, and procedure.

Stress measurement by X-ray diffraction. Adaptation of an existing photometric instrument R. Namur (*Rev. M. Tijds.*, 1959, **5,** (3), 108–114) By microphotometric measurements of X-ray diffraction films the surface stress in a normalized steel has been determined with an accuracy of ±2·5 kg/mm^2.—A. G.

Radiation damage in ferrous metals D. E. Thomas (*J. Met.*, 1959, **11,** Aug., 523–527) Radiation damage mechanisms are discussed, and mechanical and electrical effects on iron, carbon steels, and stainless steels are reviewed (14 refs).

Texture of evaporated NiFe thin films R. R. Verderber (*J. Appl. Phys.*, 1959, **30,** Sept., 1359–1363) Results of an X-ray diffraction study of orientation.

Influence of cobalt on the activation of steels in nuclear reactors P. Maldague (*Revue M. Tijds.*, 1959, **5,** (3), 115–119) Apart from cobalt, both iron and nickel give radioactive isotopes of long half-life. Calculations show that it is not worth reducing the Co content of steels for reactors below the prevailing level.

Nuclear energy applications for steel plant operations P. J. Selak and R. Tietig, jun. (*Iron Steel Eng.*, 1959, **36,** Sept., 179–184) The use of radioisotopes in steel plant operations is discussed with examples, and a table of suitable isotopes with their emission types and radioactive half-lives is reproduced.

Capture and decay of μ-mesons in Fe W. A. Barsett, F. E. Holmstrom, and J. W. Keuffel (*Phys. Rev.*, 1959, **113,** Jan. 15, 661–665).

The part played by thermal conductivity in metallurgical studies R. W. Powell (*Rev. Mét.*, 1959, **56,** July, 181–186) A brief review is given of aspects of thermal conductivity of metals as influenced by other physical properties, and by thermal treatment. Some recent results on steels and other materials are cited (15 refs).

The thermal conductivity of a molten Pu–Fe eutectic (9·5 a/o Fe) J. E. Deverall (*LA*–2269, 1958, July, pp.59; from *US Govt. Res. Rep.*, 1959, **32,** July, 17 141; no abstract.)

Thermal conductivity of metals and alloys at low temperatures. II. Data on iron and several steels between 25° and 300° K. Influence of alloying constituents R. W. Powers, J. B. Ziegler, and H. L. Johnston (*TR* 264–6; *ATI*–105923; *PB* 139747, 1951, April 25, pp.22) The maximum observed in pure iron at ∼30°K is lowered, broadened, and moved to higher temp. by alloying. The Grüneisen and Makinson theories are used in interpretation.

Thermal properties of certain metals. Part II. Iron, beryllium, iridium, palladium, platinum and tungsten T. C. Goodwin jun. and M. W. Ayton (*WADC Techn. Rep.*, 56–423; Part II; *AD*–157169; *PB* 151679, 1958, Sept., pp.321) A bibliography 1920–1957. The properties of pure iron are given (416 refs).

Ratio between the electron and vibration portions of heat conductivity in steels R. E. Krzhizhanovskii (*Zhurn. Tekhn. Fiz.*, 1959, (4), 539–545) The electron and vibratory conductivities in steel are functions of chemical composition, temp., and previous thermal treatment. In high-alloy steels and alloys the heat transfer is effected mainly by the elastic oscillations of the atoms at the corners of the crystal lattice.

The heat capacity of FeNiAl and FeCoAl alloys Yu. D. Tret'yakov and E. G. Khomyakov (*Zhurnal neorghanicheskoi khimii*, 1959, **4,** (3), 645–650) The actual heat capacity of this alloy was measured and two isothermal transformations have been noted between 300–600° and between 640–680°. The relation between high temperature transformation with magnetic hardening of the Fe–Ni–Al alloys had been confirmed. This hardening proceeds extremely slowly which confirms the high temperature exothermic effect on the heat capacity curves of the Fe–Co–Al alloys. A suggestion is offered that the λ-shaped peak between 680–750° is connected with the transformation at the Curie point.

Deviation from Matthiessen's rule and lattice thermal conductivity of alloys P. G. Klemens (*Austral. J. Phys.*, 1959, **12,** June, 199–202).

Effect of heat treatment on thermal conductivity, electrical resistance and Lorenz number of carbon steels B. E. Neimark (*Teploenergetika*, 1959, (9), 79–83) Results are given of experiments carried out on six types of carbon steel (0·15–1·25%C) on the effect of quenching and tempering on heat conductivity, electrical resistance, and the Lorenz number between 0–600°C. The physical properties of low carbon steels change little with heat treatment, but from 0·3%C upwards this influence becomes appreciable. The greatest difference between heat conductivity and electrical resistance of quenched and tempered steels occurs at 80°C. With increasing temperature the influence of the heat treatment diminishes. A formula has been evolved for the Lorenz number as a function of carbon content, which may be used for calculating heat conductivity of carbon steels with varying electrical resistance between 0 and 600°C.

Application of theory in understanding fluidity of metals J. E. Niesse, M. C. Flemings, and H. F. Taylor (*Mod. Castings*, 1959, **36,** Nov., 685–697) The property of fluidity is analysed using heat flow and fluid flow relationships. The equations developed were applied to low mp metals in a vacuum fluidity test. Low-C steel has flow and solidification characteristics similar to those of certain lead–tin alloys.—A. D. H.

Mechanical testing with a 3000°F radiant heat furnace J. K. Hoy (*Met. Prog.*, 1959, **76,** Sept., 81–83) Heating elements in this furnace are quartz pencil lamps, and the maximum temp. is reached and stabilized in 3 min or less. The internal measurements of the furnace are $4\frac{1}{2}$ in. × 10 in., and maximum power input is 37 500 W. Temperature is controlled and recorded by an ignitron controller in conjunction with a Speedomax recorder.

Malleable iron at elevated temperature L. C. Marshall and G. F. Sommer (*Prod. Eng.*, 1959, **30,** *Design Digest Issue*, Mid-Sept., 70–73) Tests for stress-rupture and creep on unalloyed ferritic and pearlitic irons up to 1200°F and up to 2300 h are reported. Extrapolations to 10000 and 100000 h are added. Levels of stress for reasonable periods of service are obtained. No significant change in structure was observed after 2300 h.

Development of high-temperature strain gauges R. Bertodo (*Inst Mech. Eng. preprint*, 1959, pp.14) A review of investigations carried out on a number of resistance alloys in a search for a gauge material operating up to 1000°C with an inherent accuracy of $\pm 5\%$ is given. Bonding media were also investigated and many factors in design and operation were evaluated. The gauge factor was found to be a function of the lattice imperfections in the wire and the material was temperature-sensitive only if these were affected by change of temp. Any factor affecting resistivity also affected sensitivity. Direct vacuum deposits may be better than wires.

Resistance of metals to high temperatures. III L. Colombier (*Bull. Cercle Etudes Mét.*, 1959, **7,** March, 411–462) In this part, the author discusses the high temp. resistance (up to 600°C) of martensitic steels of the plain-carbon, low-alloy, and alloy types. The effect of various alloy additions on the mechanical properties at elevated temp. are discussed. Various atmospheres are considered briefly (18 refs).—R.P.

Report on properties of cast iron at elevated temperatures J. R. Kattus and B. McPherson (*ASTM, STP*, 1959, (248), pp.90) The properties of six low-alloy grey and one ferritic nodular iron were measured at 800 and 1000°F by tensile, creep rupture, thermal shock, and growth tests. As-cast and annealed structures were examined. Mo was found to improve creep-rupture, Ni improved thermal shock resistance, and Cr improved structural stability. Loads that the materials should withstand in tension at 800°F for 10 years are indicated.

Malleable iron resists high temperature H. J. Heine (*Foundry*, 1959, **87,** Aug., 94–96) Tests are reported which indicate that ferritic and pearlitic malleable irons possess exceptional physical and mechanical characteristics at elevated temperatures.—A.G.

Investment-cast alloys for high-temperature service D. R. Wood (*Foundry Trade J.*, 1959, **106,** June 4, 663–668) Iron-base alloys are included. Corrosion resistance, thermal fatigue, and casting techniques are discussed.

The properties of nickel steels at low temperatures (*Mond Nickel Co. bibliography*, 1959, April, pp.25).

Metals to use at subzero temperatures J. F. Pritchard (*Chem. Eng.*, 1959, **66,** Oct. 5, 174, 176) Properties, mainly of steel, Fe–Ni alloys, and stainless steels, are tabulated and briefly discussed.

The properties of metals and alloys at temperatures below −200°C (*Mond Nickel Co. bibliography*, 1959, May, pp.62).

Measurement of the activation energy of the intergranular auto-diffusion of iron C. Leymonie and P. Lacombe (*Rev. Mét.*, 1959, **56,** June, 74–80) Results of the measurement of the penetration of ^{55}Fe and ^{59}Fe isotopes after a diffusion anneal (by measurements of residual activity after removing successive layers) the activation energy was calculated as 44 kcal/g atom for the α-phase and 41 kcal/g atom for the γ-phase (11 refs).

Self-diffusion of iron in iron silicate melt Ling Yang, Chien-yeh Chien, and G. Derge (*J. Chem. Phys.*, 1959, **30,** June, 1627) Direct measurement gave a higher value than that calculated from ionic mobility. Values are given for 1250°, 1275°, and 1304°C and activation energy is derived. Diffusion and electrical conduction appear to proceed by different mechanisms.

The diffusion of carbon during precipitation in α-iron R. H. Doremus (*Acta Met.*, 1959, **7,** June, 399–402) Activation energy for C precipitation from α-iron in wire specimens was found to be $17{\cdot}1 \pm 0{\cdot}5$ kcal/mole, by starting and completing precipitation at different temperatures. The results were the same for ageing temperatures between 0 and 170°C, and different amounts of strain. The energy measured by elastic relaxation methods is 20·1 kcal/mole, and possible reasons for this discrepancy are discussed (13 refs).

Influence of manganese and silicon on the diffusion of carbon in austenite W. Steiner and O. Krisement (*Arch. Eisenh.*, 1959, **30,** Oct., 637–640) The diffusion coefficients of C were measured in alloyed austenite containing 4·8 and 14·2 at % Mn or 6·8 at % Si in the temperature region 950–1250°C, C contents varying from 0·7 to 3·8 at %. Activation energies were determined. With a mean limit of error of $\pm 12\%$ results for the diffusion of C in steel in all three cases gave results either similar to or slightly less than those for unalloyed steels.

Investigating the non-uniform frontal diffusion of nickel in polycrystalline iron–chromium nickel alloy V. I. Arkharov, S. I. Ivanovskaya, I. P. Polikarpova, and N. P. Chuprakova (*Trudy Inst. Fiz. Met.*, 1958, (19), 23–42) The preferential diffusion mobility of Ni along crystal boundaries in the Cr–Fe–Ni austenite alloys has been confirmed. This is explained by the formation of clearly defined projections in the crystallization front along the austenite boundaries. The degree of diffusion mobility of Ni along the crystal boundaries seen by observing the microstructure of the diffusion zone, is a structure-sensitive characteristic which varies greatly, probably in relation to the mutual orientation of a given pair of crystals along the boundary where the diffusion occurs and also because of the non-uniformity of the specimen.

Microscopical and electron diffraction study of iron and aluminium carburising J. J. Trillat, L. Tertian, and M. Bonnet-Gros (*Compt. Rend.*, 1959, **249,** Oct. 12, 1299–1302) The mechanism of diffusion of C has been studied in the case of Fe where the reaction rates are high on account of the porosity and the extreme thinness of the Fe–C films. Cementite decomposition is also observed. In the case of Al, the formation of C_3Al_4 was observed.

Electron metallographic evidence of diffusion of hydrogen through tin plate containers E. Lanterman (*J. Appl. Phys.*, 1959, **30,** July, 1084–1086) Tin surfaces of containers which had failed by H_2 formation owing to corrosion by grape-fruit juice showed rupture and blistering and enlargement of grain boundaries.

The surface tension of liquid metals and slags. (Part I) I. Kašik and J. Skala (*Hutn. Listy*, 1959, **14,** (7), 602–608) An instrument was developed for the measurement of surface tensions by means of the method of the maximum bubble pressure below the surface of the liquid. The instrument was tested with liquid metals of known surface tensions, and the effect of the addition of V and Ti on the surface tension of low alloy Cr–Ni was studied.

Comments on the use of inert markers for diffusion studies in plastic phases M. Cagnet and J. Moreau (*Acta Met.*, 1959, **7,** June, 427–429) [In French] A letter. A criticism of a paper on this subject by Engell and Wever (1957, **5,** 695) is followed by a letter (429) [in German] by Engell and Wever replying to the criticism.

The influence of hydrogen on the properties of cast iron P. von der Forst (*Giesserei*, 1959, **46,** Nov. 19, 931–937) Scavenging grey iron melts with H_2, N_2, and A using quartz tubes gave an increasingly chilled structure to wedge and quench specimens with increasing temperature, the greatest effect being obtained with H_2. Subsequent inoculation with Ca–Si alloy or gas scavenging with graphite tubes produced a grey solidification structure. The mechanism of these reactions is discussed.

Hydrogen and segregates in flaking T. E. Scott and A. R. Troiano (*J. Met.*, 1959, **11,** Sept., 619–622) The two main theories of flake formation—i.e. the transformation stress and hydrogen pressure theories, are discussed, and methods of producing flake-free sections are suggested (18 refs).

Some observations on hydrogen cracks K. Kornfeld (*JISI*, 1960, **194,** April, 474–479) [This issue].

Hydrogen in steel (*Hutnicke Aktuality*, 1958, **14,** pp.107) **Some methods of producing steel with a low hydrogen content** A. M. Samarin (9–21) After indicating the solubility of H_2 in Fe and its harmful effects, which are bound to be present in view of the high pressure exerted by H_2 (12000 atm at normal temperature in steel with 0·0005% H_2 content), the following methods of removing H_2 from molten steel are outlined: control of the decarburization rate during the period of the melt, bearing in mind the decisive influence of the moisture content of the slag-forming additions; blowing of the melt with CO in arc furnaces; slow filling of ingot moulds with molten metal and long maintenance of the meniscus in a liquid state; vacuum melting or treatment in a vacuum down to 11 mm with a period of treatment of up to 15 min. **Production of steel with a low hydrogen content** N. A. Chvorinov (22–37) Published assessments of H_2 contents of acid and basic OH steels and electric furnace steel are examined, and present methods of determination of the H_2 content of steels are reviewed. In the light not only of results already published, but of these experiments, it is concluded (1) the H_2 content of the bath, in both the boil and reduction periods is primarily dependent on the absorption of H_2 by the bath; (2) the source of H_2 for this absorption may be either additions, e.g. limestone and ferro-alloys, or the surrounding air; (3) in arc furnaces H_2 is absorbed by the bath either exclusively or for the most part in the high temperature zone below the electrodes; (4) the removal of H_2 in the boil is impeded by the reverse absorption of the H_2 liberated from the bath by the boil and (5) the solubility of H_2 in the bath may be reduced by increasing the oxidation potential of the furnace atmosphere, e.g. by an excess of unconsumed O_2 during the oxide boil. Similar results may be obtained from the conversion of H_2 into more stable forms, e.g. HF. Apart from the following methods of reducing the H_2 content hitherto used for electric furnace steels: (1) the use of additions from which moisture and H_2 have been removed; (2) the use of a carbon boil after formation of the reduction slag; and (3) blowing of the finished melt and the furnace atmosphere with dry air; the use of an oxygen boil with an excess of oxygen also greatly reduces the H_2 content. This oxygen boil must be followed by reduction without tapping the oxide slag. If this slag is not tapped, then the favourable conditions for H_2 absorption by the bath occurring during the change-over from the oxidation period to the reduction period until a new slag is formed are not created. Experiments have shown that by means of this oxygen boil it is possible to reduce the H_2 content to values which almost correspond to theoretical, but that as a result of ore boil and, in many instances, of oxygen boil, the H_2 content is substantially greater than these values. In the high temperature zone of the arc certain reactions occur, in particular dissociation of H_2 and water vapour into atomic H and O and hydroxyl ions, so that the dissociation and partial pressure of atomic H are many times greater than at normal furnace temperatures (1600–1650°C), and H and N absorption beneath the electrodes are correspondingly increased. This can be offset by blowing in O_2 at a low level of utilization. It is proposed that tests should be made with electrodes with channels for delivery of small quantities of O_2 or a suitable dry inert gas directly into the space beneath the electrodes for gradual local discharge and by the simultaneous addition of a suitable mixture, e.g. $SiO_2 + CaF_2$, to reduce the dissociation of atomic H by forming HF. Experiments with the measures indicated show that it is possible to reduce the H_2 content to less than 2·0 ml/100 g, and it is considered feasible to obtain a mean value of 1·5 ml/100 g. **The dependence of the hydrogen brittleness of steel on the content of oxide inclusions** J. Foryst (47–59) Since segregations of non-metallic inclusions have a considerable

influence on the formation of cracks and hydrogen blow-holes, research was conducted to determine their effect on the sensitivity of mild steel to the action of H_2. Various amounts of Si–Mn–Al alloy were added to deoxidized Armco iron, and ingots were cast and hot-forged and drawn into 3 mm dia. wire. Samples were then used to determine the content and composition of the oxide inclusions; these were also anodically separated or sublimed *in vacuo*. The methods used were described in articles by Foryst *et al.* Other specimens were used to determine elongation during cathodic polarization in the initial state (0·05% oxide inclusions), after 24 h heating in moist H_2, and after degasification *in vacuo* at 800°C. The polarization solution was N H_2SO_4 with the addition of 2×10^{-3} mols As_2O_3/l. at 20°C. Repeated bending through 180° was carried to fracture of the samples saturated with cathodic H_2. The brittleness caused by the H_2 was determined as $K=\frac{n_0-n}{n_0}\times100\%$, where n_0 is the number of bending cycles withstood by a specimen before saturation and n the number after saturation. It was found that there was no connexion between the brittleness of the steel so caused and the content of oxide inclusions. Microscopical study showed that plastic deformation of steel on cathodic polarization is caused by the accumulation of H_2 in internal blow-holes and micropores in the active layer lying just below the surface, but that the varying thickness of the active layer has a marked effect on the plastic deformation. The thickness of the layer in mild steels is dependent on the distribution of the non-metallic inclusions and in no way on their quantity. It is also concluded that hydrogen brittleness is not directly dependent on the pressure of internal fissures and blow-holes. **The depth of penetration of cathode hydrogen and the magnetic properties of silicon and chrome nickel austenitic steels** L. Kozlowski (60–64) In other experiments (in the press) it was found that cathodic polarization of low-alloy and Si steels and Ni produced a marked growth in their coercive forces, which was especially strong in Si steels. The present paper relates to experiments to assess the effect of the depth of penetration of cathodic H_2 in 3·2%Si steel on this phenomenon, by polarization in N H_2SO_4 with the addition of 0·2 g As_2O_3/l. at 25°C with a current density of 0·1 A/cm.^{2} The coercive force was measured by the ballistic method in an open magnetic circuit with a solenoid of 200 Oe/A capacity. Previously the specimens were heated for 2 h *in vacuo* at 950°C and cooled in the furnace. Both the relative and absolute growth in the coercive force were measured owing to the variations in the values of specimens in the initial state (0·4–0·6 Oe). It was found that the coercive force rises rapidly for 20 min up to a depth of 0·35 mm and ceases to grow after an hour; at depths greater than 0·35 mm the values are very much less. Values for the coercive force at various levels after 2 h electrolysis reveal in general no sort of clear relationship to the depth of H_2 penetration. Further experiments were conducted on 0·25%C, 16·8%Cr, 9·5%Ni steel by measurement of the magnetic field intensity of 'hydrogenated' specimens. It is concluded that the results obtained confirm the conclusions of Eisenkolb and Ehrlich (*Arch. Eisenhüt.*, 1954, **25,** 187) that H_2 only penetrates into thin surface layers of austenitic steels. In the light of the experiments this surface is only a few microns thick; on its removal the steel regains its original magnetic properties. It is also apparent that it is precisely this surface which prevents the free passage of H_2 out of the bulk of the specimen into the atmosphere. **The effect of electrolytic saturation with hydrogen on the brittleness of iron and nickel wires** M. Smialowski and H. Angersteinova (76–87) Penetration of H_2 into metals is dependent on the concentration of atomic H on the boundary between the metal surface and the surrounding medium. If on one side of the surface the concentration of H is greater than on the other, conditions are favourable to its penetration. This complex phenomenon shows the following stages: formation of atomic H through thermal dissociation or chemical or electrochemical reaction, adsorption of H-atoms on the metal surface, dissolution in the metal as atoms or ions (solid solution) and diffusion into the depth of the metal. As H_2 penetrates, these processes are reversed. The effect of electrolytic saturation with H_2 in N H_2SO_4 with the addition of 0·01 g As_2O_3 on mild steel and nickel wires was examined. Saturation is a two-stage process. Probably the crystal lattices of the surface layers of the metal are first saturated with H_2 and H^+, while in the second stage bubbles are formed containing compressed H_2. Some of the bubbles close to the surface burst under the pressure and H_2 diffuses. The first saturation stage produces brittleness, which is only imperceptibly increased in the second stage and comes to a constant value. Specimens of steel wire saturated only to the first stage lose their brittleness after storage at ordinary temperature while specimens saturated to the second stage, which causes plastic and elastic deformation, do not recover their plastic properties. In the first stage Ni absorbs much more H_2 than steel, but under otherwise equal conditions the saturation period is much longer. The second stage has less influence on the change in the properties of nickel. **Hydrogen brittleness of coated springs** A. Dvořák (88–94) Data are given in this article obtained during detailed research into H_2 embrittlement of galvanically coated wires. From observations of mass-produced spiral springs the hypothesis was formed that springs galvanized in an alkaline bath are more brittle than Cd-plated springs. This concerned <1 mm dia. steel springs which after plating were all deprived of H_2 by heating at 200°C. The main aim of the research was therefore to compare the fall in properties of spring steels during galvanizing and Cd plating. This required a test machine to handle specimens of 1–2 mm dia., not hitherto described. The machine developed for bending strength tests on a draw bench is shown. The results obtained for uncoated steel, cathodically treated in 10%H_2SO_4 at 2 A/dm^2 for 15 min; steel galvanized in a cyanide bath at 1 A/dm^2 for 90 min; and steel Cd-plated at 1 A/dm^2 for 90 min; were plotted as bending strength–log time of dehydrogenation by heating at 250°C. The plot shows the striking retarding effect of these coatings on the effusion of H_2, which is about one-tenth that from the uncoated steel, as is the rate of recovery of mechanical properties. In particular an appreciable drop in brittleness of the galvanized specimens was only observed when blistering of the coating occurred. No blistering of the Cd coating was established. Neither of these sets of specimens recovered the original bending strength even after 20 h heating (for the uncoated steel <10 min only were necessary). This barrier formed by the coatings, which is highly impervious to H_2, may be explained by diffusion of the coating into the base metal. Cd plating forms a visibly more complete union between the coating and the base metal, so that there are less H_2 cavities; thus the bond is stronger and therefore the adhesion of the coating to the base metal is also better. **The effect of the carbon content on certain properties of transformer steels** G. A. Garnyk (95–107) A description is given of experiments in the development of improved transformer steels at the Electrostel' works in Russia, vacuum casting, rolling, and heat treatment techniques and the effects of various compositions. Such steels should not contain more than 0·01%C; Si contents up to 6·2% can produce good transformer steels, but they can only be rolled where the content of the impurities is as low as possible, and in general steel with a content of 3·2%Si is more readily workable. Impurities not only cause rolling difficulties but make the material magnetically harder. In general the structure should have coarse grain, thin grain boundaries, and good homogeneity, and should show no signs of precipitated carbon.—M.T.

Influence of small additions of tungsten, molybdenum, titanium and niobium on the heat resistance of certain austenitic alloys of the type Kh20N20 and Kh20N35 between 1100 and 1300° Z. P. Kichigina (*Trudy Inst. Fiz. Met.*, 1958, (19), 149–152) Small Mo additions (up to 1%), W (up to 2%), and Ti (up to 1·8%) have practically no effect on the heat resistance of the Fe–Cr–Ni alloys. Up to 0·5%Nb lowers their resistance, especially in the presence of Mo, W, or Ti. W up to 0·2% also causes a decrease in heat resistance.

Boron in steels. I. Steels with a low boron content D. Pittoni (*Met. Ital.*, 1959, **51,** Jan., 21–30) The discovery and subsequent historical development of boron is described. An account is then given of the effects of boron on temperability, surface hardening, workability, and technical properties for steels with low boron content. Methods of manufacturing and analysing these steels are then described.
II. **Steels with a high boron content** (31–34) This second part describes the importance of boron steels for the nuclear energy industry. A table shows the composition and physical, mechanical, and technological properties of certain boron steels which can be used for nuclear purposes and these are then described. Finally an account is given of the production of boron steel for nuclear uses.

Effect of boron on the properties and heat treatment of stainless spring steel A. G. Rakhshtadt and A. M. Grishin (*Stal'*, 1959, (9), 830–835) Austenitic N36KhTYu steel was used with 0·003–0·007%B, which was forged, hot-rolled, and hardened and rolled into strip 0·25–0·3 mm thick. Hardness and elasticity were measured, the latter by resonance vibration. The mechanism of action of the B and the structures produced are discussed at length. Optimum effects are found at the limit of solubility, were 0·005%. Quenching is important, tempering conditions are unchanged.

A creep-resisting steel containing 7%Cr G. A. Mellor and S. M. Barker (*JISI*, 1960, **194,** April, 464–474) [This issue].

Stainless steels R. E. Paret (*Met. Prog.*, 1959, **76,** Oct., 131–134) A survey of a number of stainless steels and their uses is given including hardenable austenitic steels, low-Co steels for nuclear reactors, corrosion-resisting and N-containing steels, and of the hot extrusion of stainless steels.

Electric Furnace Co. completes extensive research facitilies (*Iron Steel Eng.*, 1959, **36,** July, 152, 154) The laboratory and research facilities recently opened by Electric Furnace Company, Salem, Ohio, is equipped for research into and development of techniques for the furnace treatment of ferrous and non-ferrous metals and alloys. The 5-zone continuous pilot strip furnace and some of the heat treatment furnaces are described.

Two new research laboratories (*J. Met.*, 1959, **11,** Aug., 508–509) A brief description of the new research centres opened by Republic Steel Corporation at Independence, Ohio, and by Harbison–Walker Refractories Co., near Pittsburgh.

METALLOGRAPHY

On methods of stereometric metallography J. Likeš (*Hutn. Listy.*, 1959, **14,** (7), 573–580) The problems of determining the amount and dispersion of precipitates and phases in a metal, or of determining the true spatial grain size from planar measurements are discussed, and the appropriate mathematical expressions are developed.—P.F.

Examination of the structure of metals (*Técn. e Ind.*, 1959, **37,** July, 944–946) An elementary description of equipment with 10 plates of metal structures.—S.H.–S.

The emission electron microscope. Application to the study of the emission of secondary electrons under the action of a beam of ions R. Simon (*Mét. Corr. Ind.*, 1959, **34,** Mar., 98–120) A detailed study of the principles governing the formation of images and resolving power is followed by a description of the instrument which has been developed by CRNS.

Simple auxiliary equipment for preparing evaporation layers for investigations using the electron microscope G. Pohlmann and F. Oberlies (*Radex Rundsch.*, 1959, Oct., 684–688) Evaporation techniques used in preparing replicas are reviewed and compared, and a description is given of a device for use in this process which has been developed in the Max Planck Institut.

Use of the electron microscope for the direct examination of metals and alloys in thin laminae C. Beauvais (*Mét. Corr. Ind.*, 1959,

34, June, 247–257; July–Aug., 291–301) The principles underlying the method are reviewed, three methods of producing the laminae described, with particular reference to electrolytic polishing, and several applications discussed, the ferrous examples being an 18/8 stainless steel and a plain carbon steel (12 refs).

A metallograph for the mill G. H. Boss (*Met. Prog.*, 1959, **75,** May, 81–83) A portable metallographic instrument including polishing and etching equipment is described, which is suitable for shop use. Examples of its application to the examination of heavy components are given; optical examination up to 900×, and photography up to 250× are feasible.

Investigation of the temperature changes of the microstructure in ferromagnetic substances by means of the electron microscope I. S. Slutnikova, G. V. Spivak, and I. M. Saraeva (*Izvest. AN Ser. Fiz.*, 1959, **23,** (6), 734–736) It has been shown that the secondary-emission microscope has considerable sensitivity so that it makes it possible to observe the changes in the crystal domains which occur with increasing temperature. It was possible to investigate the domain structure of grains (0001) of a cobalt monocrystal up to ~240°.

Transmission quantitative metallography J. W. Cahn and J. Nutting (*Trans. Met. Soc. AIME*, 1959, **215,** June, 526–528) Electron microscopy of thin films can give no. of particles per unit volume, volume fraction, and surface to volume ratio of a second phase. The calculations and corrections needed are given.

Metallography: Electrolytic polishing of specimens (*Met. Treatment*, 1959, **26,** May, 203–204) Apparatus developed by Zeiss of Jena is described.

A new instrument for the electrolytic pretreatment of metals for metallographic examination F. Rummele (*J. Sci. Ind. Res.*, 1959, **18A,** Aug., 347–351) Apparatus produced by Carl Zeiss VEB is described and illustrated.

Technique for preparing thin films of α-iron D. G. Brandon and J. Nutting (*Brit. J. Appl. Phys.*, 1959, **10,** June, 255–256) An electropolishing method for preparing foils for electron microscopy is described.

Electrolytic pre-treatment of metals for metallographic examination (*Min. J.*, 1959, **252,** June 19, 671–673) Equipment developed by Zeiss is described.

Use of diamond abrasives in metallographic problems E. C. Olden (*PB* 151042, 1958, March, pp.21) Diamond abrasives were found to be suitable for preparing metallographic specimens for retention of nonmetallic inclusions or surface distortion, or ensuring sufficient flatness of field.

News from the Institute of Iron Metallurgy in Gliwice J. Goczal, C. Gawin, and A. Chaj (*Hutnik*, 1959, (4), 167–172) Alkylsulphonate reagent for revealing grain size in steel is used. The authors give the results of treating certain tool steels of varying grain size. The results of similar treatment of structural steels using a Polish reagent 'alkilo' are then given. The following deductions are drawn: (1) In order to reveal the grain boundaries of what have been austenite grains, a solution of picric acid with an addition of Teepol can be used; (2) The sample should be treated for about 5 to 12 min at room temperature and this time can be reduced by heating; (3) The sample must be polished before microscopical examination.

Development of the metallographic etching pattern taking into account the electrolytically dissolved quantity of metal E. Kunze and E. Horn (*Arch. Eisenh.*, 1959, **30,** Oct., 613–617) Investigations are described of the possibility of establishing conditions for reproducible etching results on a series of commercial steels, using electrolytic etching. The steels were etched in various electrolytes and the effects of heat treatment and structure on the results were examined. Specimens covered a range of low, medium, and high-alloy steels.

On the thermal etching of silicon iron C. G. Dunn and J. L. Walter (*Acta Met.*, 1959, **7,** Sept., 648–650) Striations appear on grains oriented near (100) and (111). Grains near (110) appear almost specular but have very small facet-like steps. The studies were carried out in A with traces of O_2.

Contribution to electrolytic-potentiostatic etching, with particular reference to the coulometric determination of depth of etching H. Ludering (*Arch. Eisenhütt.*, 1959, **30,** Oct., 605–611) By standardizing conditions, and using etching solutions free from oxidizing agents, reproducible etching results were obtained by electrolytic etching of a dead mild steel, a medium-C unalloyed steel, and a white Thomas pig iron. Experimental conditions, equipment and results are described.

Examination of microstructure without the cutting of samples J. Evsymontt (*Hutnik*, 1959, **26,** (7–8), 321–324) The method depends on the hand polishing of a particular spot on the object to be examined and subsequent etching with a suitable reagent. Next a coating of suitable lacquer is applied. When this is dried the resulting replica is removed and examined under a microscope. Other substances than lacquer can be used. Experiments have shown the method to be very accurate.

Investigation by means of microbeams of steel deformed at different speeds at elevated temperatures M. Ya. Fuks and L. Ya. Gol'dshtein (*Izvest. AN Ser. Fiz.*, 1959, 629–634) The specimens were prepared from St25 steel after normalization from 860° and tempering at 620°. The mean linear dimensions of the crystals determined by two exposures according to the method suggested by P. B. Hirsch in *Acta Cryst.*, 1952, (5), 61, amounted to 25 μ. The standard specimens were subjected to long-term fracture tests in a standard machine under different conditions (tabulated) and etched to a depth of 0·3 mm. The X-ray radiographs are given, but they show changes only in the mosaic structure.

Etching figures on Fe and Fe–Si alloys for the determination of crystallographic orientation and relation to the structure of ferro-magnetic domains F. Brossa, A. Ferro, and G. Venturello (*Met. Ital.*, 1959, **51,** April, 139–141) Reagents have been developed for Fe and Fe–Si alloys—particularly $HgCl_2$ and $HgNO_3$ to produce clear etching figures which facilitate quick approximate identification of crystals. The results obtained have been compared with the determination of orientation by X-rays using a method similar to that used by Schulz for tracing polar curves. The method is then used to correlate to the orientation of the various types of domain structures observed on iron and Fe–Si alloys. These findings agree with results obtained by Bozorth and Williams. Some new observations are made concerning the breaking of the domains into smaller jagged forms. In addition to research into magnetic properties the Bitter figures seem useful to determine the orientation and co-action state of materials even if in general by itself it does not always permit clear determination of the orientation of the individual crystal.

Etching reagents for dislocations in metal crystals L. C. Lovell, F. L. Vogel, and J. H. Wernick (*Met. Prog.*, 1959, **75,** May, 96, 96B) General methods of preparation, precautions to be observed, and a data sheet with recommended etching solutions and time for various metals are reviewed.

Etch pits in iron R. B. Liss (*Acta Met.*, 1959, **7,** March, 231–232) A letter. Contrary to reports by Suits and Low (*ibid.*, 1957, **5,** 285) and Boswell (*Metal Progress*, 1957, **72,** (6), 92) which indicate that segregation of solute (C) to dislocation sites is necessary before selective etching will occur in the formation of etch pits in slip bands in Si iron, the author has developed etch pits in what appear to be glide bands without any pretreatment.

Some new applications of the Castaing electronic microprobe and their practical importance J. Philibert and H. Bizouard (*Rev. Mét.*, 1959, **56,** July, 187–200) Recent improvements in the Castaing–Descamps electronic microanalyser are described, and the results are given of some IRSID investigations covering a variety of applications including the study of segregation in fine precipitates, heat resisting steels, and investigation of specimens taken during a Thomas blow.

Isolation of non-metallic inclusions by direct chlorination M. Mandl, M. Kaše, R. Freiwillig, and J. Dostal (*Hutn. Listy*, 1959, **14,** (7), 617–620) Apparatus for the direct chlorination of steel samples was developed, and methods for the analysis of the chlorination products are given in detail. This process of inclusion analysis is rapid, and results compare well with standard methods, as was shown in the present work, the Klinger–Koch procedure being used for comparison. With rimming steels however, it gave somewhat low results.—P.F.

Study on the electrolytic isolation of carbide from bearing steel M. Kondo and T. Shibaki (*Nippon Kinzoku*, 1958, **22,** Oct., 525–528) Carbides were isolated in 0·2 N HCl + 5% citric acid, or 0·5 N HCl. Residues containing much metallic iron were found with steels containing appreciable amounts of Cu, Sn, or As, nearly all of which appeared in the residue. The Cu content probably partially covered the surface of the sample, preventing complete isolation of the carbide.—K.E.J.

Study on carbides in steel by electrolytic isolation. I. On the electrolytic isolation of cementite by the Na citrate solution method and the change of Mn partition between ferrite and cementite in carbon steel on heat treatment K. Miyauchi, K. Tasaka, M. Arakawa, and T. Kunitake (*Sumi. Met.*, 1959, **11,** Jan., 14–21) Optimum conditions for the method were established, with c.d. in the range 3·5–5 mA/cm² the amount and carbon composition were almost theoretical. The concentration of Mn in globular cementite reaches nearly the equilibrium value, but that in cementite from lamellar pearlite produced by continuous cooling is low, the more so with high rates of cooling.—K.E.J.

Study on the carbides in high speed steels by electrolytic isolation. II. Behaviour of carbides due to heat treatment in high-W and Mo high speed steels S. Koshiba, S. Kimura, and H. Harada (*Tetsu to Hagane*, 1959, **45,** June, 608–614) Carbides in high-W and Mo steels were examined and analysed after various treatments of the steels. $M_{23}C_6$ was pptd. in high-W steel by tempering to 750°C; in Mo steel the amount of MC increased with tempering, and $M_{23}C_6$ appeared on tempering to above 575°C (14 refs).—K.E.J.

Study on carbide in commercial special steels by electrolytic isolation. VIII. On carbides in high-C high-V high speed steels T. Sato, T. Nishizawa, and K. Murai (*Tetsu to Hagane*, 1959, **45,** May, 511–516) The effects of C, W, and V content on the constitution of MC, M_6C, and $M_{23}C_6$ are discussed. If the C/V ratio is too low, $M_{23}C_6$ is not formed, and the steel cannot be hardened; if too high, there will be excessive retained austenite after quenching. The optimum relationship is $C(\%) = 0{\cdot}19 + 0{\cdot}017 \times W(\%) + 0{\cdot}22 \times V(\%)$ (16 refs).

Radioactive tracer investigation of inclusions in alloy steel castings P. W. Clark and D. H. Houseman (*Brit. Found.*, 1959, **52,** Oct., 445–450) The amount of zircon originating from oil-bonded zircon moulding sand or zircon-containing mould wash in the interior of modified 18-8 stainless steel castings was shown to be negligible. Irradiated samples of sand and mould wash were used to prepare the moulds. An appreciable amount of zircon was found to a depth of ¼ in. from the as-cast surface but a comparable mould treated with mould paint showed less penetration, and gave improved surface finish. A large globular inclusion in the surface of one casting contained slag, zircon, and quartz. Possible sources of these constituents are discussed.—A.D.B.

The γ-grain of steels: new method of study and the role of aluminium nitride J. Pomey and G. Vigneron (*Compt. Rend.*, 1959, **249,** Oct. 28, 1661–1663) A method of treating a polished austenitized surface with a metallic vapour of an alloy which does not transform at a temperature at which epitaxis occurs is described. AlN is shown to oppose grain growth.

Morphology and crystal structure of carbides precipitated from solid solution in alpha iron W. C. Leslie, R. M. Fisher, and N. Sen (*Acta Met.*, 1959, **7,** Sept., 632–644) Electron microscopy and diffraction show the carbide precipitated from carbon and carbon-Si steels to be dendrites with or without oblong plates according to quenching condition, and consisting of cementite. No ε-carbide was indicated. Identifiable particles were formed at 250°C in the time taken to produce 70% completion of the precipitation and at 150° much longer than for 100% precipitation. In the alloy with 3·25%Si the carbides appear as

lenticular discs on the {100} ferrite planes. This carbide was not identified.

Method of combating non-metallic inclusions in magnesium iron V. I. Soldatenko and M. I. Rotenberg (*Lit. Proizv.*, 1959, (5), 7–8) The method adopted at the Kolomensk Locomotive Works was to add Mg iron to the iron in the ladle. With the sulphur iron carefully freed from slag at 1450–1460°, a bell containing 0·35% pure Mg was immersed, when the slag is again removed and fresh sulphur iron is poured in at 1540–1560° with simultaneous addition of 0·3–0·62-Si-75. The tapping temperature is 1390–1420°. This process, it is claimed, gives good results.

The nature of precipitates forming in modified 12%Cr steels above 550° J. Ježek, J. Koutsky, and J. Pluhař (*Hutn. Listy*, 1959, **14**, (5), 469–472) X-Ray, electron diffraction, and other methods were used to identify the carbides precipitating in several 12%Cr steels containing variable amounts of W, Ni, Mo, V, and Co. The precipitate, which forms on prolonged heating, is Fe_2W. It occurs in steels containing δ-ferrite, and also in purely martensitic steels. It can exist up to the Ac_1-point. In steels containing Mo but no W the isomorphous intermetallic phase Fe_2Mo forms; this is stable up to 700°C. In Cr steels free from further alloying elements small quantities of Cr_2N are found in addition to the carbide $(Fe, Cr)_{23}C_6$. Some of the results obtained are not in accord with the earlier work of Kuo (*JISI*, 1953, **173**, 363, and 1957, **185**, 297).

General specification on the size of grain in metallography and mineralogy F. Fabriani (*Bol. ABM*, 1959, **15**, July, 551–566) Stemming from the ferrous and non-ferrous grain-size specifications of ASTM, after reviewing iron particle size or measurement of granular structure, linked to the author's previous general specification on grain size, a metric specification is presented covering non-ferrous grain size, supported by numerous equations, sections and graphs, with tabulated mathematical statistics.—S.H.–S.

Investigations of a new kind of secondary crystallization in 3%Si Fe alloys K. Detert (*Acta Met.*, 1959, **7**, Sept., 589–598) [In German] A phenomenon has been observed in thin specimens in which grain growth stops before two-dimensional selective growth begins. The selective growth appears to be due to surface energy differences between the different crystallographic faces.

Investigation of the fine structure of Fe–Si alloys under deformation G. M. Vorob'ev (*Izvest. AN Ser. Fiz.*, 1959, **23**, (5), 601–605) Pure iron, and alloys containing 1, 2, and 4% Si were examined for the effect of the degree of deformation on microhardness, the change of the average dimensions of the blocks, the changes in the distortions of the IInd order, and on the percentage of substances not contributing to the diffraction of X-rays.

Crystallographic orientation of single iron crystals obtained by critical elongation and recrystallization Z. Bojarski (*Prace Inst. Hutn.*, 1959, (1), 19–23) First a survey of the literature is given followed by a description of the method of obtaining large crystals in sheets of 'Armco' iron. The crystallographic orientation was obtained by means of Laue back scattering and it was found that the crystals show no preferred orientation. Since the crystals were obtained by a small degree of strain and recrystallization, it seems that if strain is small the slip mechanism is influenced by secondary factors, such as impurities, and there is no reorientation due to the direction of the force.

On the theory of the formation of solid solutions in metallic systems A. N. Krestovnikov and V. N. Vigdorovich (*Zhurn. Fiz. Khim.*, 1959, **33**, (1), 78–82) The analytical results show that the existence of a constant temperature stability of the solid solution which forms with interatomic bonds between compoments is impossible. Data for systems in which an increase in temperature stability of the main component with formation of solid solutions occurs have been studied.

Solid state transitions in manganese and iron solid solutions A. Hellawell (*J. Less-Common Met.*, 1959, **1**, April, 110–112) Body centred-face centred transformations are briefly considered.

Studies on lattice transformation of iron alloy and cobalt alloy. III. T. Honma (*Denki-Seiko*, 1959, **30**, March, 159–170) [In Japanese].

Influence of carbon content on phase composition and some characteristics of low alloy, high-speed steels for casting N. A. Erofeev (*Chern. Metallurg*, 1959, (4), 79–83) With an increased carbon content a continuous impoverishment of the solid solution in W, V, and Cr takes place both after hardening and after three-stage tempering at 560°. The W and V distribution between the phases depends on the carbon content; the most favourable distribution is found with a carbon content of up to 1·1%. In the distribution of the alloy elements between the solid solutions and the carbon phase during tempering, the carbide phase is enriched to a larger extent in Cr than in W and V.

The equilibrium phase diagram. Its significance to foundrymen in solidification and heat treatment J. F. Wallace (*Foundry*, 1959, **87**, Sept., 84–89) The typical diagram is interpreted. **Grey iron** R. A. Clark (108–115) The metallography of cast iron, graphite distribution and form, and the effects of P and Si are reviewed with notes on heat treatment. **Steel and malleable iron** B. C. Yearley (116–121) The freezing process is reviewed and shrinkage effects and other phenomena in the mould are described.

Nickel or chromium percentage in the primary crystal of alloy white iron I. Fukumoto and N. Shibata (*Nippon Kinzoku*, 1958, **22**, Oct., 536–540) Alloy irons containing Ni, Cr, or both were cast in various moulds and examined. The concentration ratio of Ni in the separated cementite residue (γ-Ni) became lower and γ-Cr higher with short heat-treatment. The higher the cooling rate, the lower γ-Cr and higher γ-Ni. The Ac_1 and Ar^1 temp. of castings are raised by annealing at 800° or 900°C, and this depends on the variation of Ni and particularly Cr in the primary crystal.—K.E.J.

Progress in studies of isothermal and continuous cooling transformations of French steels carried out at IRSID A. Constant (*Centre Doc. Sidér. Circ.*, 1958, (5), 1085–1094) The author reviews the methods used in these studies and the results obtained. He then discusses possible applications of continuous cooling curves of low-alloy steels.—R.P.

The time law of pearlite transformation E. Greulich (*Arch. Eisenh.*, 1959, **30**, April, 219–225) In order to investigate the laws governing the formation of pearlite by isothermal transformation, platelet specimens of steel with 0·7%C, and with 0·7%C and 0·65%Ni were austenitized at 840–1050°C, held at 540°C for various periods and rapidly quenched. From the results of Rockwell hardness tests, the changes in hardness as a function of holding time were used to determine the half-life period of pearlite formation. The mean distance of the pearlite grain mid-points was also determined by microscopical measurement in three mutually perpendicular planes (13 refs).

Transformation diagrams for austenite in steel ShKh15 (*Metallov. Obra. Met.*, 1959, (5), 31–34) Composition, critical points, and recommended cooling rates are also given.

On the structural mechanism of formation of austenite during the heating of steels B. K. Sokolov and B. D. Sadovskii (*Metallov. Obra. Met.*, 1959, (5), 7–14) Low alloy steels were examined by the methods of vacuum metallography and transformations were directly observed. Effects of rate of heating and composition on grain size were noted and mechanisms are discussed.

Temperature range of decomposition of the residual austenite during tempering of carbon steels G. T. Nazarenko (*Metallov. Obra. Met.*, 1959, (5), 28–30) Magnetic saturation studies, which are more sensitive than dilatometric curves, show that the values for the lower temperature range of residual austenite decomposition so far published are too high. For a tempering time of 2 h, decomposition proceeds at 100–275°C with a maximum at ~200°C. With increasing time the range narrows.

Theoretical analysis of the influence of carbon on the kinetics of isothermal disintegration of super-cooled austenite L. N. Aleksandrov (*Fiz. Met.*, 1959, **7**, (2), 169–173) Two equations are given for calculating the time of the complete transformation of a given volume of hypoeutectoid austenite. It appears from these that change in carbon content influences the process of isothermal transformation above 650°C. With an increased carbon content the decrease in the absolute activation energy of transformation is not large but the surface tension is appreciable. The influence of carbon on the kinetics of isothermal decay of the super-cooled austenite in hypereutectoid steels may be similarly analysed.

The formation of cementite during the quench-hardening of steels A. Stähler and W. Klempt (*VBI-Z*, 1959, **101**, June 21, 757–759) A review of the effect of cementite on the hardness and wear properties of steels. Formation of cementite depends on the amount of carbon in the steel and on the heat-treatment. Quench-hardening of eutectoid and hypereutectoid steels and case-hardening are briefly dealt with.—T.G.

Phase transformations in hardened steel causing dimensional changes Z. Csepiga (*Acta Techn.*, 1958, **22**, (3–4), 285–310) [In English] The transformation processes of the structural constituents of a hardened ball-bearing steel are examined; by comparing changes of dimension with those of a similar specimen of annealed steel of the same composition using a differential dilatometer, the effect of thermal expansion is eliminated, and changes in length due to phase transformations can be directly measured. A method is described by which the effects due to martensite and austenite transformations can be separated and the influence of different tempering methods is examined (23 refs).

Transformations in the solid state of iron alloys with cobalt and palladium V. V. Kuprina and A. T. Grigor'ev (*Zhurnal neorganicheskoi Khimii*, 1959, **4**, (7), 1606–1612) The quenched and annealed alloys were examined by differential thermal analysis and microstructure in multi-temperature cuttings of 2;5;10;20;30;40; and 50 atoms % of Pd. It was found that polymorphic transformation occurs in the alloys with the above percentages of Pd atoms. This transformation is accompanied by the formation of a wide two-phase domain (α+γ) which narrows with increasing Pd content and with increasing temperature. The three-phase domain (α+γ+γ_1) forms in iron-rich alloys.

The surface martensite of a Fe–Ni–Co alloy and the general conditions for its formation A. Mašin and O. Bakalikova (*Acta Techn.*, 1959, **26**, (3–4), 403–418) [In German] The surface martensite is shown to be the same as that of Fe–Cr–Mn–C and Fe–Mn–C alloys. Chemical inhomogeneity, crystallographic orientation of crystal lattice and grinding effects are responsible for its formation.

The formation of spheroidal graphite in hypereutectic cast iron melts J. Motz (*Giesserei*, 1959, **46**, Dec. 3, 953–957) The literature is reviewed, and experiments described, from which it is concluded that spherolithes crystallize directly from hypereutectic melts treated with Mg. The fact that spherolithic Kish seldom occurs is attributed to the improved 'wettability' of graphite by iron after Mg treatment. It is also concluded that, at least in the slightly hypoeutectic to the hypereutectic range, a eutectic crystallization; melt→austenite+spheroidal graphite must occur. As the spherolithes are found preferentially in the centres of the austenite grains, it is assumed that the spherolithes so formed are immediately surrounded by an austenite shell (24 refs).

Precipitation process of carbon in alpha-iron T. Suzuki and Y. Tomono (*J. Phys. Soc. Japan*, 1959, **14**, May, 597–601) Electron microscope studies and internal friction measurements were made. The mechanism is formulated as the sum of two processes, one being absorption of C atoms by the precipitates by way of dislocations and the other their absorption through the precipitate surfaces by a diffusion-limited process.

Influence of bismuth on the graphitization of iron during solidification T. Hsiao and L. Chi-chiung (*Fond. Ital.*, 1959, **8**, June, 225–228; from *Scientia Sinica*, 1958, **7**, (10))

Bismuth is now regarded as a useful alloying element in the production of malleable cast iron. The main problems of shortening the cycle of annealing and the production thicknesses have been solved by using Bi as an alloying element. This article gives some preliminary results on its effect in the graphitizing process.

Study regarding graphite nucleation and the kinetics of graphitization in white cast irons P. Laurent and M. Ferry (*Fonderie*, 1958, Aug., 351–360) In this third part the authors discuss results obtained and accepted to date; this is followed by a critical study of proposed theories and suggestions are made regarding the mechanism of graphite formation. The number of nuclei formed are represented as a function of temp. The concentration gradient and growth of graphite is discussed.—R.P.

Kinetics of first-stage graphitization in commercial white irons J. Burke (*JISI*, 1960, **194,** April, 443–445) [This issue].

Factors influencing the formation of graphite or carbon in cast iron A. Bordes (*Metalen*, 1958, **14,** Oct. 15, 298–303) The article gives a useful review on some theoretical and practical data concerning the factors which influence the formation of graphite or carbon in grey, white, malleable, and nodular cast iron during as well as after solidification. It is in three sections, the first concerns the mechanism of graphite formation, the second the influence attributable to chemical composition, of the raw materials employed, melting, pouring temperatures, and annealing, while the third discusses certain theories referring to the basic reasons for some of the effects described in the previous section.—F.R.H.

The mechanism of graphitization of Fe–C–Si alloys D. S. Gill and D. S. Epplesheimer (*Foundry*, 1959, **87,** Aug., 60–61) Following micrographic studies of an iron containing 2·45%C and 1·45%Si a mechanism for the early stages of graphitization is proposed. Secondary carbides are said to grow at the expense of primary cementite in austenite and then decompose into temper carbon and carbon depleted austenite.—A.G.

Study on the graphitization of high carbon steel. II. Influence of various elements on the graphitization of high carbon steel 2. N. Yamanaka and K. Kusaka (*Tetsu to Hagane*, 1959, **45,** May, 499–506) The steel was made from electrolytic or sand iron, with Al additions up to 0·05%. Si promoted, and Mn inhibited graphitization after water quenching and cold drawing. Cr, Mo, and W inhibited graphitization. Ti, Zr, and B markedly promoted graphitization after water quenching; V had a similar effect at over 0·1%. Ni promoted graphitization after cold drawing; Cu had little effect; Nb inhibited it. Sn inhibited graphitization after water-quenching and cold drawing, and P, Te, Sb, and As restrained it.

The determination of the A_1 critical range for forging irons G. F. Tikhonov (*Lit. Proizv.*, 1959, (1), 42–43) Experiments were carried out to obtain dilatometric curves for 1·29%Si forging iron which clearly indicate the critical points. The following factors emerge from the study of the critical temperature range. During heating of the ferrito-pearlitic structure, formation of the γ-phase starts along the grain boundaries. Since this phase is the result of the reaction between the α-phase and C, so reverse carbon segregation from the graphitic inclusions into the solid solution likewise occurs along the grain boundaries. The ferrite-pearlitic matrix of the iron has a structure consisting of grains of ferrite in a pearlitic network after a certain degree of austenitization has occurred. The increase in volume during the (ferrite + graphite)→(pearlite + graphite (0·2%)) transformation confirms that during the reverse solution of the graphitic inclusions in the γ-solid solution the locations vacated by the graphite are either not filled at all or only to a minor degree. Consequently after austenitization of ferrito-graphitic annealed iron, around each graphite inclusion there are partially or totally vacant sites. The opinion of other authors that these vacant sites play a dominant role in the breakdown of austenite is questionable, since reverse segregation of graphite does not take place at an increased rate, but at the same rate as segregation during the first transformation.—M.T.

Effect of phase transformation following diffusion V. T. Borisov, V. M. Golikov, and G. V. Shcherbedinskii (*Doklady AN*, 1959, **125,** (4), 786–789) The influence of the interfaces of the metal grains on the diffusion rate was studied. Specimens consisted of Fe–Ni alloys, chosen because at room temperature they may exist either with austenite or martensite structures. Results show that over a wide temperature range differences in the rates of diffusion have been found which correspond to different pretreatments. At high temperatures, the diffusion coefficients for both structures practically coincide. At lower temperatures, up to 800°, the diffusion rate of iron in the alloy subjected to transformation is less than without transformation. Finally at 700° the position is reversed, i.e. the rate of diffusion in the alloy with transformation is greater than in the alloy without.

Austenite formation in the hypo and hypereutectoid and eutectoid plain carbon steels C. Dasarathy (*Trans. Indian Inst. Met.*, 1959, **12,** June, 135–153) Steels with pearlite, pearlite-ferrite, and pearlite-cementite structures in the lamellar state and carbide in ferrite in the spheroidized state were used. Nucleation sites and growth patterns of austenite are discussed and factors controlling pearlite solution are studied. Solution of cementite is slower than of ferrite, and diffusion rates are considered and relations to distance between carbide particles on number of spheroids in unit volume are established.

Concerning the temperature of the beginning of the austenite transformation into ferrite during accelerated cooling E. I. Mirovskii (*Chern. Metallurg.*, 1959, (4), 85–87) Specimens of two types of steel were investigated, by heating in a non-oxidizing atmosphere at 1000° kept for 20 min and then, immersed in water for 0·05 to 0·5 sec so that they were cooled to different temperatures. The transformation of austenite into ferrite under these conditions begins at the A_3 point. The measurements were carried out in specially constructed apparatus.

Orientation relationship between austenite and martensite in steels with low carbon content P. Dörnen and W. Hofmann (*Arch. Eisenh.*, 1959, **30,** Oct., 627–636) Single crystals were produced from high-purity iron wire, carburized in CH_4/H_2 mixtures, Laue orientation photographs of the austenite taken and the material transformed to martensite by quenching in Hg. X-ray goniometer photographs of the martensitic structure were taken, and the orientation of the habit phases was determined. The results of derived pole figures were compared with results reported by other authors, and the transformation was found to agree with the Kurdjumow–Sachs orientation relationship. The paper was followed by a discussion (21 refs).

Study by microcalorimetry of the transformation of the austenite of a steel with 12%Mn and 1·3%C G. Collette (*Met. Corr. Ind.*, 1959, **34,** July–Aug., 269–290; Sept. 335–365; Oct., 401–412) Apparatus used is described and microsections are shown after various heat treatments. The thermal changes for various transformations and precipitation reactions in the metal were obtained and are discussed, and activation energies and kinetics are evaluated for metal with and without cold-working. Relations between the time of the maximum rate of precipitation, t_m, the rate of cold-working and the temperature are discussed. A new method of calculating the coefficients for Wert's law relating to precipitation rate and conclusions on the isothermal austenite transformation kinetics of unworked steel are given (32 refs).

Non-diffusion formation of austenite when heating quenched steel B. K. Sokolov and V. G. Gorbach (*Trudy Inst. Fiz. Met.*, 1959, (22), 123–135) During the rapid heating of the quenched steels 40N19G, 40Kh12, and 40KhGS a contour system forms on the polished surface. It appears rapidly at the locations of the martensite bands. The appearance of these contours during the phase transition from α- to γ-martensite suggests that this transition occurs because of a crystallographic ordering similar to the reverse martensite transformation. During the rapid heating of these steels the original grain is restored in the process of phase crystallization. This restoration is the result of reverse crystalline orientation during the direct and the non-diffusion transformation.

The nature of martensitic transformations G. V. Kurdyumov (*J. Met.*, 1959, **11,** July, 449–453) A review of the work carried out in recent years leading to the establishment of the true nature of the martensite transformation in terms of nucleation depending upon free energy and atomic kinetic energy data.

Comments on 'accommodation strains in martensite formation and the use of a dilatation parameter' L. Kaufman and J. W. Christian (*Acta Met.*, 1959, **7,** March, 216–218; 218–219) Two letters (*ibid.*, 1958, **6,** 377). Kaufman comments on the application by Christian of Eshelby's strain energy calculations to the nucleation problem of a thin oblate spheroid of martensite; he compares the results of the analysis with previous calculations of $E_1 + E_2$, where E_1 is the dilatational strain energy and E_2 the shear strain energy per unit volume, and comments on nucleation considerations advanced by Christian, showing some discrepancies between the Eshelby–Christian and Knapp–Dehlinger results (*ibid.*, 1956, **4,** 289). A reply by Christian is given (11 refs).

Investigating the kinetics of martensite formation during plastic deformation P. V. Novichkov (*Zavods. Lab.*, 1959, (2), 166–170) The relation between the magnetic characteristics and the stages of transformation are obtained from the magnetic permeability. In order to obtain calibrated curves, a special anisometric apparatus is described of increased accuracy and sensitivity.

The behaviour of internal friction associated with the process of martensite-type transformation Wang Yeh-ning and Chu Chiang-chung (*Acta Phys. Sinica*, 1959, **15,** July, 341–352) Alloys of Fe with 17·5 and 12·8% Mn were examined with a torsion pendulum, and peaks were observed in martensite and reverse martensite transformation regions. The mechanism is discussed.

Development of new mechanisms and techniques for obtaining steels in the ultra-high strength range D. Gullotti, E. Eichen, and J. W. Spretnak (*WADC Techn. Rep.*, 56–555; *AD* 130755; *PB* 131238, 1957, May, pp.56) The superimposition of plastic deformation on the austenite-martensite transformation and the production of high N-low C martensite were studied.

Anomalous kinetics of the bainitic transformation just above the martensitic range M. F. Smith, G. R. Speich, and M. Cohen (*Trans. Met. Soc. AIME*, 1959, **215,** June, 528–530) Acceleration of the isothermal transformation just above M_s appears to be due to the formation of martensite activated by the start of the bainite transformation and rapid propagation of martensite plates supersedes further bainite growth and produces a product resembling bainite which appears sooner than bainite itself could. In the later stages the nucleation of martensite becomes more difficult and the normal bainite reaction sets in.

The nature and structure of the sigma phase in transition alloys E. G. Ramachandran and L. J. Balasunderam (*NML Techn. J.*, 1959, **1,** May, 28–31) A general account of the σ-phase in Fe–Cr, Fe–V, Fe–Mo, and Fe–W and nonferrous systems, with crystal lattice data (36 refs).

The Fe–Cr–Co–C quaternary system D. Coutsouradis and L. Habraken (*Cobalt*, 1959, (4), Sept., 3–27) Isothermal sections of the system for 850°, 1000°, and 1100°C are obtained and structures are shown. Much heat-treatment information is presented.

The system iron–phosphorus–silicon R. Vogel and B. Giessen (*Arch. Eisenh.*, 1959, **30,** Oct., 619–626) A description is given of thermoanalytical, microscopical, and chemical investigations to determine equilibrium conditions in the high ranges of P and Si contents. The existence of a ternary compound $FeSi_4P$ was established—on melting, this compound breaks down into a series of liquid and vapour phases, or reforms into the original compound

on cooling from these two phases. The behaviour of the group IV elements Si, Ti, and Zr in forming ternary compounds in the Fe–Si–P, Fe–Ti–P and Fe–Zr–P systems is compared.

Regarding the new high-striction alloys of the binary systems Fe Pt; Fe Pd; and Ni Pd Z. I. Alizade (*Izvest. AN Ser. Fiz.*, 1959, **23,** (3), 416–417) Important information should be obtainable from investigation of magnetostriction of binary and multi-component alloys consisting of the ferro-magnetic elements of group VIII with the non-ferromagnetic elements of the same group. The results of the present investigation have shown that, in fact, within the composition of the binary alloys Fe–Pt; Fe–Pd; and Ni–Pd there is a number of alloys with a maximum positive (Fe–Pt and Fe–Pd) as well as with a maximum negative (Ni–Pd) striction saturation.

Structural investigation of iron aluminium alloys with abnormal electro conductivity E. N. Vlasova and L. N. Fedotov (*Izvest. AN Seriya Fiz.*, 1959, **23,** (3), 403–404) In Fe–Al alloys containing from 3–10%Al by weight, the formation of the k state i.e. the state originating during tempering of quenched and deformed alloys, which is accompanied by an abnormal increase in electrical resistance, has been investigated. A comparison of the data obtained from the structure with those obtained from the change in electrical resistance supplies an explanation of the causes of this anomaly. In alloys with 10% by weight of Al tempered at 300°, the structure domain is ordered with sizes of the order of 100 Å. The increase in the electrical resistance is due to the increased distance between electrons and the domain boundaries when the dimensions of the domains are comparable with the length of the electron waves. In alloys with 8%Al by weight the change in the electrical resistance is explained by the formation of a close-packed arrangement of atoms.

Phase relationships in the system iron–aluminium oxygen L. M. Atlas and W. K. Sumida (*PB* 151000, 1957, Feb., pp.49) Compatibility relations; dissociation equilibria, lattice parameters and structural relations are discussed in the light of the literature and of results obtained from experiments carried out at the Armour Research Foundation. Compounds identified are enumerated and discussed (28 refs).

The ternary metallic bond in the iron–chromium titanium system N. G. Boriskin and I. I. Kornilov (*Zhurnal neorganicheskoi khimii*, 1959, **4,** (9), 2171–2173) The calculated and observed lines of the X-ray spectrum of the alloy as cast are tabulated. All lines correspond to a body-centred lattice of α-Mn type with 58 atoms per cell. The lattice parameters calculated from the double lines correspond to a large angle of reflection and the number of atoms per cell is 59. The Fe–Cr–Ti system answers to the conditions for the formation of an α-phase of this type because the atomic radius of Ti (1·46) is larger than that of Cr (1·27) and of iron (1·26).

Investigations of the iron palladium system V. V. Krupina and A. T. Grigor'ev (*Zhurnal neorganicheskoi khimii*, 1959, **4,** (3), 655–661) This system was investigated by methods of differential thermal analysis, hardness by Brinell, microstructure, electrical resistance, and its temperature coefficient. The solubility of Pd in α-iron does not exceed 5 atom%. The polymorphic α⇌γ transformation of iron is reduced by Pd.

CORROSION

Corrosion and passivity U. F. Franck (*Corros. Anticorros.*, 1959, **7,** March, 83–97) The characteristic types of passivity are discussed in relation to data obtained from current-potential curves. The properties of passive layers and their conditions of formation and destruction are discussed, with reference to the literature (62 refs).

The corrosion of iron and steel K. A. Chandler (*Gas Works—Coking*, 1959, **150,** Sept. 5, 7–12) The mechanism of rusting and measures for its prevention with special reference to coke-oven conditions are discussed.

The application of Faraday's Law to the study of the anodic dissolution of metals M. Froment (*Corros. Anticorros.*, 1959, **7,** Jan., 13–19; *Rev. Nickel*, 1959, **7,** March, 98–109) Electrical measurement of the amount of dissolution and anode potential and the relationships between electrical conditions and surface state are dealt with (51 refs).

The significance of the Flade potential M. J. Pryor (*J. Electrochem. Soc.*, 1959, **106,** July, 557–562) After a critical review of previous explanations of the Flade potential, an explanation is offered based on a single phase passive film of γ-Fe_2O_3, with non-uniform defect concentration and type. It is considered that the reaction determining the potential is that between excess O_2 in the outer p-type layers of the passive film and H^+-irons and electrodes (26 refs).

Report of the activities of Committee No.IV of ABEM during 1956. II. Technical report (*Assoc. Belge pour l'Etude, l'Essai et l'Emploi des Materiaux*, 1957, March, pp.55) This report covers the activities of the anti-corrosion committee of the Association. The programme of work, experimental stations, atmospheric corrosion, and corrosion in specimens partly or fully immersed in river or sea-water are dealt with, and comparative corrosion tests using various types of protective coatings are reported and discussed in detail.

Report of the activity of Committee No.IV of ABEM during 1957. II. Technical report (*Assoc. Belge pour l'Etude l'Essai et l'Emploi des Materiaux*, 1958, May, pp.54) Preliminary sections outline nomenclature and the main types of change in protective coatings applied to steel, followed by the principle adopted for evaluating the percentage of surface corrosion of the specimens. Three campaigns on atmospheric corrosion are reported, dealing with anti-corrosion paints, a comparative study of surface preparations and the use of mist inhibitors and wash-primers, and of epoxy-resin based paints. A report on corrosion of specimens partly or totally immersed in river or sea water (1956 campaign) is followed by a section dealing with a study of the natural corrosion of structural steels.

Chemical proof of H_2O_2 formation in the atmospheric corrosion of metals I. L. Roikh (*Zhurn. Fiz. Khim.*, 1958, **32,** (5), 1137–1142) A description is given of the chemical methods used for demonstrating the formation of H_2O_2 during the atmospheric corrosion of both electro-positive and electronegative metals. In all 19 metals were tested and all tests confirmed these conclusions.

Investigating the mechanism of atmospheric corrosion of iron in the presence of sulphur dioxide Z. A. Iofa and G. G. Besproskurnov (*Zhurn. Fiz. Khim.*, 1957, **31,** (10), 2236–2243) It has been shown that the corrosion of iron in the atmosphere increases with an increase in the SO_2 concentration and falls with a reduction in humidity. With a relative humidity below 65–70% corrosion is practically arrested. During corrosion for 25–30 h in a humid atmosphere a layer of rust forms which slows up the process. Corrosion begun in the atmosphere by SO_2 continues in a completely dry atmosphere at a lower rate.

Mechanism of stress corrosion of austenitic stainless steels in chloride waters R. W. Staehle, F. H. Beck, and M. G. Fontana (*Corrosion*, 1959, **15,** July, 373t–381t) Stress-corrosion cracking of austenitic stainless steels was studied under various conditions of stress, chloride concentration, complete immersion of specimens, intermittent wetting and drying, and presence of oxygen. Stress-corrosion cracking occurred at stresses as low as 2000 psi at 50 ppm, NaCl. A three-dimensional study of the cracks formed under beam-loading conditions leads to the theory that crack development is due to electrochemical action in the pits initially formed, the stresses serving to provide anodic areas at the base of the pits.

Remarks on corrosion diagrams V. Cupr and J. B. Pelikan (*Werks. Corr.*, 1959, **10,** Sept., 544–547) It is shown that current potential curves cannot be superimposed in rectangular coordinate systems or partial currents added to give total current, if there is a mathematical correlation between the anodic and cathodic reactions. The implications are discussed in relation to the investigation of corrosion processes.

Mechanism of metal corrosion in narrow slits IV. Corrosion of stainless steels I. K. Marshakov and I. K. Rosenfel'd (*Zhurn. Fiz. Khim.*, 1958, **32,** (1), 66–72) The behaviour of Cr steels under corrosion in narrow slits in a 0·5 N NaCl solution has been investigated. It was found that steels with 13–17%Cr corrode in narrow slits and show intensive pitting. The depth of this corrosion in the slits increases when the steel in the slits is in contact with the steel in the electrolyte owing to the formation of active-passive cells, the metal in the slits serving as anode. The cause of these couples is the limited access of oxygen to the slits.

Prime reasons for metal failures G. A. Nelson (*Chem. Eng.*, 1959, **66,** June 29, 132, 134, 136) A survey of eight chemical plants and nine oil refineries is used to give the main causes of failure of metals, mainly corrosion or stress-corrosion, and protective measures are indicated.

The ubiquity of localized corrosion R. B. Mears (*J. Electrochem. Soc.*, 1959, **106,** May, 467–468) The view is expressed that because of crystal imperfections, segregation of impurities grain boundaries, and dissimilar phases, localized corrosion is to be expected. It is therefore necessary to explain why uniform corrosion so commonly occurs.—A.G.

Product fallout – a serious corrosion problem W. E. Kemp (*Ind. Eng. Chem.*, 1959, **51,** July, 71A–72A) A note on protection systems for steelwork in areas where atmospheric pollution adds to the aggressiveness of the environment. Examples are illustrated.

Corrosion of cast iron: effects of anti-freeze mixtures in road vehicle engine cooling systems (*Auto Eng.*, 1959, **49,** Aug., 293) A note from BCIRA on changes in antifreeze solutions. Corrosion in Diesel engines may be due to the oxidation of glycol to formic acid.

Metallic finishes for services equipment D. W. Smith (*Electro. Met. Fiz.*, 1959, **12,** Sept., 331–337) Several examples of corrosion, mostly non-ferrous, are given with some discussion of conditions to be met, materials used, and specifications made use of.

Culprit in stainless failures E. G. Brush (*Chem. Eng.*, 1959, **66,** Oct. 5, 178) Carbon in molten Na is shown to lead to attack.

Some factors affecting the performance of condenser and heat exchanger tubes P. T. Gilbert (*Chem. Ind.*, 1959, July 11, 888–895) The corrosion of the tubes and factors affecting it are discussed. Non-ferrous tubes are included.

Influence of photosynthesis on the corrosion of steel in sea water A. Hache, L. Barricty, and J. Debyser (*Corros. Anticorros.*, 1959, **7,** Feb., 56–61) The relation between the O_2 content of sea water containing increased amounts of O_2 as a result of photosynthesis and the corrosion of steel specimens immersed in the water is established. It is shown that corrosion is proportional to dissolved O_2 content both in sea water and in a solution of NaCl.

Corrosion in sour water strippers J. F. Mason jun., and C. M. Schillmoller (*Corrosion*, 1959, **15,** July, 358t–362t) Al, Monel-metal, and stainless steel have been found useful in the construction of stripper units designed to remove H_2S and other contaminants from waste waters. However, carbon steel is the more usual construction material and can be protected by filming amines or by gunite or alloy linings, except in the worst conditions. Improved plant practice could reduce the corrosion problem considerably.—J.F.S.

Corrosion of Types 316 and 317 stainless steel by 75% and 85% phosphoric acid A. R. Morgan jun. (*Corrosion*, 1959, **15,** July, 351t–354t) Plant experience has shown that types 316 and 316L stainless steels can be used in 75% or 85%H_3PO_4 only below 100°C. Laboratory and pilot plant tests both indicate that higher operating temperatures should be possible. Type 317 is better than 316 in both pilot plant tests and in actual use. The worst corrosion was under stagnant conditions. Welded areas were not preferentially attacked.

Corrosion problems associated with sour gas condensate production D. R. Fincher (*Corrosion*, 1959, **15,** Aug., 413t–416t) Sour gas condensate has been produced from a group of wells in Texas since 1953 in which the sour gases have been recirculated to the formation.

The resulting corrosion problems have been kept under control by designing equipment to remove water at all possible points, by construction in suitable materials, and by a constantly supervized inhibitor programme.—

Corrosion of reinforcing steel in concrete in marine atmospheres D. A. Lewis and W. J. Copenhagen (*Corrosion*, 1959, **15,** July, 382t–388t) Corrosion of steel in concrete is a major problem in coastal areas of South Africa. The mechanisms that can cause corrosion in these circumstances are discussed and experimental evidence given. The severity of attack depends mainly on the NaCl concentration at the steel surface in the concrete. Significant factors include depth of cover, protective coatings, curing, and water/cement ratio. Accelerated and natural weathering tests are in progress.

Corrosion of type 310 stainless steel by synthetic fuel oil ash H. L. Logan (*Corrosion*, 1959, **15,** Aug., 443t–446t) The minimum temp. at which a 21·2%Ni–24·8%Cr steel was attacked by several mixtures of V_2O_5 and either Na_2SO_4 or $NaVO_3$ was 1075°F for a mixture of 65%V_2O_5 and 33%$NaVO_3$. From this temp. up to 1890°F an unidentified phase was produced at the interface of the steel and the compound or mixtures of compounds formed. There was evidence that this phase penetrated into the steel at grain boundaries. Spectrochemical analysis of a fused synthetic mixture of the slag indicated that it contained some of the components of the steel in the same proportions as they were present in the steel.

Contribution to the study of the corrosion of a semi-stainless steel by Lacq effluent J. A. Ternisien, A. Servasier, S. Barbezat, and M. Bonnet-Gros (*Compt. Rend.*, 1959, **249,** Oct. 28, 1655–1677) Electron micrographs show an outer friable layer and an internal compact protective layer of pyrite and pyrrhotite.

Corrosion resistance of aluminium in contact with stainless steel H. Zeiger (*Aluminium*, 1959, **35,** July, 394–395) References to the literature indicate that Al and stainless steel in electrical contacts are liable to corrosion on exposure to sea-water spray or atmospheric action near the sea. This effect is much less pronounced when the metals are suitably insulated (20 refs).

Study of corrosion on various metals in the calcining of aqueous radioactive wastes containing zirconium fluoride and aluminium nitrate as bulk salts E. J. Tuthill and R. F. Domish (*BNL*–510 (*T*–123), 1958, May, pp.48, from *US Govt. Res. Rep.*, 1959, **32,** July 17, 141; no abstract).

High temperature corrosion of metals C. J. Guare (*Mat. Design. Eng.*, 1959, **50,** Aug., 110–114) The factors controlling the corrosion processes are discussed. Alloy composition, atmosphere composition and flow, surface treatments, and effects of thermal cycling on protective films are considered.

Stress corrosion of 12% chromium stainless steel R. E. Lochen and E. R. Miller (*Ind. Eng. Chem.*, 1959, **51,** June, 763–764) Tests on 403 0·05 and 0·50 Mo steels and 422 stainless are reported. The latter is the most resistant.

The stress-corrosion cracking of mild steel in coal gas liquors R. N. Parkins and R. Usher (*J. Appl. Chem.*, 1959, **9,** Sept., 445–456) Locations of corrosive attack in a coal-gas cleaning plant are observed and various suggestions as to mechanism are made.

Some metallurgical factors affecting stress corrosion cracking of austenitic stainless steels H. H. Uhlig and R. A. White (*ASM preprint* 167, 1959, pp.18) Tests in boiling 42%$MgCl_2$ show that alloys low in C and N do not fail in 260 h, but commercial type 304 alloys fail within 0·2–1·4 h. Austenitic 20%Cr 20%Ni steel with N~0·002% is also resistant and C here confers resistance to cracking. Nb stabilizes the γ-phase in 18-8 and as quenched the steel is susceptible to cracking. Ti has little effect and Nb has no effect in commercial samples. Si increases resistance and Co and B appear beneficial. It is concluded that α-phase is resistant. Mechanism is discussed.

Stress corrosion and creep of high-strength steel wire for prestressed concrete F. Schwier (*F. & G. Rundschau*, 1958, Dec., 122–132) Stress corrosion and creep properties of several high-strength wires and wire strands were examined, and the results are discussed. Drawn and annealed wire was much less susceptible to stress corrosion than wire heat-treated to a martensitic structure.

Notch sensitivity effects in stress corrosion and hydrogen embrittlement tests on high strength steels B. F. Brown (*Corrosion*, 1959, **15,** Aug., 399t–402t) Because different high-strength steels differ in their susceptibility to brittle fracture in the presence of a notch this phenomenon will hasten to varying degrees the failure by cracking of stress-corrosion specimens so giving an erroneous impression of their rates of stress-corrosion cracking. Heat-treatment affects differently their susceptibility to the two phenomena. Extensive data are given for a stainless steel tempered at 875° and 1075°F. Identification of the two types of crack is discussed and crack growth behaviour is expressed graphically as a means of distinction.—J.F.S.

Stress corrosion cracking of oil country tubular goods R. L. McGlasson and W. D. Greathouse (*Corrosion*, 1959, **15,** Aug., 437t–442t) A new, notched-ring test method for studying stress corrosion resistance of steels is described. Data are given on the stress-corrosion cracking of different steels in H_2S–brine systems under different applied stresses and after various hardening treatments. Tests to reproduce the cracking encountered in 'sweet' wells lead to the conclusion that this is due to sulphide in low concentrations. 15 ppm H_2S have been sufficient to induce cracking. All steels are susceptible to sulphide stress corrosion above certain limiting stresses and hardness values but alloyed steels are worse than unalloyed steels for a given strength level.

Intercrystalline corrosion of austenitic stainless steels L. Clerbois, F. Clerbois, and J. Massart (**Electrochimica Acta*, **1,** 1959, April, 70–82) Potentiostat measurements show three kinds of attack to be possible, generalized, intercrystalline, and corrosion in an oxidizing medium. The technique is claimed to offer an acceptance test superior to those in use, whose defects, in fact, it can be used to explain.

Copper in boiler tubes B. F. Peters and R. D. Barer (*Corros. Techn.*, 1959, **6,** Oct., 322) A letter. Comments are made on a paper by Spurr entitled 'The significance of copper deposits associated with a boiler tube failure' (1959, **6,** Aug., 233). A different interpretation is assigned to the failure there described.

Cavitation erosion: a case of conjoint action A. K. Lahiri and T. Banerjee (*NML Tech. J.*, 1959, **1,** May, 38–40) The mechanism of the process and studies of a corroded pump impeller of cast iron are described. A table of cast alloys and their properties and corrosion-test values is included.

Cavitation damage—a review of present knowledge D. J. Godfrey (*Chem. Ind.*, 1959, June 6, 686–691) Suggestions for protective measures are added.

Galvanic corrosion of copper alloys and stainless steels in cellulose wash waters E. Uusitalo (*Tekn. Kem. Aikak.*, 1959, **16,** May, 273, 275, 277, 279–281) Solutions containing SO_2 at pH 3·5–10 and 18°C were studied and polarization curves were traced for two stainless steels and five Cu alloys. The effect of agitation was also examined.

Cast iron and fuming sulphuric acid J. Beran (*Werks. Korr.*, 1959, **10,** Nov., 665–666) Strictures on cast iron for use in $H_2S_2O_7$ are held to relate to cast iron with above 0·4%Si. Cast iron for such uses should contain no free Si. Practical experience has shown that such cast iron is suitable for use with $H_2S_2O_7$.—L.J.L.

Wiggin high-nickel alloys and hydrochloric acid, hydrogen chloride and chlorine H. Wiggin & Co. (*Publication*, 1530, 1958, Oct., pp.52) Tests in comparison with mild and stainless steels and cast iron are tabulated.

Weld corrosion in type 316 and 316L stainless steels and related problems M. E. Carruthers (*Weld. J.*, 1959, **38,** June, 259s–267s) Results of a questionnaire on the use and performance of types 316 and 316L steels are reported with recommendations for future practice.—A.G.

Corrosion of stainless-steel welds formed with carbon-dioxide shielding B. E. Hopkinson and D. W. McDowell (*Weld. J.*, 1959, **38,** April, 188s–193s) The effects on weld chemistry and corrosion resistance of stainless-steel weldments made under CO_2 shielding and A+1%O_2 respectively (10 refs).

Corrosion characteristics of types 304 and 304L weldments M. W. Marshall (*Weld. J.*, 1959, **38,** June, 247s–250s) From a review of published data it is concluded that in type 304 steel, carbide precipitation may impair welded joints. Type 304L, with less than 0·3%C is therefore recommended for welding purposes.

Muffler [silencer] corrosion—its cause and control R. A. Heath (*SAE Trans.*, 1959, **67,** 553–558) Tests on hot-rolled steel, hot-dipped galvanized sheet and aluminized steel are reported, the damage being done by acid condensate. Stainless steel is good but expensive. Improved design as well as improved materials may assist.

Role of corrosion engineers in water supply P. Beermann (*J. Am. Water Works Assoc.*, 1959, **51,** Sept., 1181–1184) Experience with the San Diego supply system is described and a control programme is advised. The engineer can make recommendations as well as operating and maintaining cathodic protection systems.

Influence of water composition on the corrosion of steel G. B. Hatch and O. Rice (*J. Am. Water Works Assoc.*, 1959, **51,** June, 719–727) Tests using Ca salts at 35°C are reported using sulphate, bicarbonate, chloride, and mixtures of these and noting $CaCO_3$ deposition. The corrosion rates were generally low with the solutions used.

Solving corrosion problems at electrical generating plants L. Baskette (*Corrosion* 1959, **15,** June (*Technical Topics*) 95–96) Some of the corrosion problems encountered at power generating stations situated near salt water are considered and their solutions discussed. Reference is made to water pollution, heat exchanger tubes, condensers, concrete pipe, ground water wells, transmission tower footings, fences, and structural steel.—J.F.S.

Factors affecting the corrosion of steel by oil-brine-hydrogen sulfide mixtures D. W. Shannon and J. E. Boggs (*Corrosion*, 1959, **15,** June, 299t–302t) Laboratory studies were made to determine what variables affect the corrosion process in oil-brine-H_2S mixtures so that a suitable screening test for inhibitors could be devized. The initial corrosion rate depends on the H_2S concentration but after one day becomes independent because diffusion of the gas controls the reaction rate. At very high H_2S concentrations the type of iron sulphide layer formed slows down the corrosion. NaCl additions prevent this layer from protecting the steel but above 1% salt a reduction in rate again occurs, perhaps due to inhibition by the salt itself.—J.F.S.

Five case histories on corrosion problems in nitric acid and ammonium nitrate production and storage D. M. Carr (*Corrosion*, 1959, **15,** June, (*Technical Topics*), 99–100) Failures of stainless steel and Al in contact with NH_4NO_3 and HNO_3 due to stress corrosion and other causes are discussed.—J.F.S.

Heat bibliography 1957 (*DSIR Mech. Eng. Res. Lab., Heat Division*, 1958, pp.376) Sections on corrosion (9½ pp. in double columns), furnaces (222–225), and high temperatures (263–267) are included, each in alphabetical order of authors.

β-Ferric Oxyhydroxide and green rust D. R. Dasgupta and A. L. Mackay (*J. Phys. Soc. Jap.*, 1959, **14,** July, 932–935) X-Ray data are presented to confirm the formation of β-FeOOH, but crystalline $Fe(OH)_3$ was not found.

On the structure of green rust of iron H. Yoshioka (*J. Phys. Soc. Jap.*, 1959, **14,** July, 974) Electron diffraction patterns are shown and the structure deduced is slightly different from that in the previous abstract.

Formation of iron oxide incrustations in steam boilers with multiple circulation N. N. Man'kina, M. M. Przhiyalkovskii, Yu. M. Bulavitskii, and I. N. Petrova (*Teploenergetika*, 1959, (2), 79–83) The rate of formation of these incrustations depends on the heat load. An increase in the total iron concentration in the boiler water increases the velocity of the process. The main components of the 'iron' incrustations are iron oxides deposited on the heated surfaces mainly as magnetite, Fe_3O_4.

The iron is concentrated in the water of the boiler to a lesser degree than the easily soluble substances (chlorides, sulphates of sodium, etc.).

High-temperature oxidation of iron whiskers J. V. Laukonis and R. V. Coleman (*J. Appl. Phys.*, 1959, **30,** Sept., 1364–1368) Studies on clean and already oxidized single crystal iron surfaces are described.

Surface oxide film on tinplate T. Oyama (*Toyo Kohan*, 1956, **4,** Dec., 16–24) [In Japanese].

Lattice parameters in the α-Fe_2O_3–Cr_2O_3 solid solution R. K. Di Cerbo and A. U. Seybolt (*J. Am. Ceram. Soc.*, 1959, **42,** Sept., 430–431) The data are of value in the study of scales formed on Fe–Cr alloys such as stainless steel.

Crystalline magnetite from corrosion of iron T. Hagyard and B. R. Penfold (*Chem. Ind.*, 1959, June 13, 727–728) A letter. The crystals were observed in a domestic refrigerator working without corrosion inhibitor.

Oxidation of metals under the influence of the glow discharge in oxygen R. I. Nazarova (*Zhurn. Fiz. Khim.*, 1958, **32,** (1), 79–86) Cu, Al, Fe, and to a lesser extent Mg and Zn when serving as electrodes for glow discharges in O_2 oxidize at a rate exceeding by a factor of 10 the rate of oxidation in air. The oxidation of the anodes is different for each metal obviously because of the properties of the oxide films. The structure of these films has also been investigated.

High-temperature sulphiding of iron alloys in hydrogen sulphide hydrogen mixtures E. W. Haycock (*J. Electrochem. Soc.*, 1959, **106,** Sept., 764–771) Pure iron and Cr steels were used and scale formation was observed at 400–550°C at pressures up to 600 psi with a partial H_2S pressure of 0·6 psi up to 500 h. A mechanism is suggested and also an explanation for the effect of H_2. A lattice irregularity is postulated to be known as an 'E' centre.

The role of the metal-ion concentration cell in crevice corrosion G. J. Schafer and P. K. Foster (*J. Electrochem. Soc.* 1959, **106,** May, 468) Arguments are proposed to support the view that crevice mouth attack is a special case of differential aeration and that the metal-ion concentration cell plays no part.—A.G.

Atmospheric corrosion of steel P. J. Sereda (*Ind. Eng. Chem.*, 1959, **51,** Sept., Part I, 65A–66A) Exposure tests on a low-C steel are evaluated in terms of temp., SO_2 concentration, and surface moisture.

Electron microscope investigation of the structure of metal corrosion layers and adhesive deposits G. Pfefferkorn (**Mitteilungen der Vereinigung der Grosskesselbesitzer*, 1958, Dec., 375–381) Iron and copper on oxidation form acicular growths normal to the surface. The structure of these deposits, their mechanism of formation, and their mode of growth with temperature are discussed. The black deposits in boiler tubes are examined and shown to be of similar constitution. These fibre structures form filter media upon which other materials are readily deposited, and may show catalytic activity.

Corrosion studies. II. Influence of the electrical properties of the electrode on the potential measurement of polarization using an interrupted current M. Pražak and V. Pražak (*Coll. Czechoslovak. Chem. Comm.*, 1956, **21,** (1), 63–72) [In German]. **III. Anodic passivation of iron and cathodic passivation of magnetite** (73–78). **V. Mechanism of chemical passivation and corrosion of metals** (3), 564–570).

Studies on corrosion XXII. Activation energy of passivation of iron in sulphuric acid K. Smrček, I. Sekerka, and J. Vorlíček (*Coll. Czech. Chem. Comm.*, 1959, **24,** Oct., 3335–3340) Temperature and concentration dependences are measured.

Investigating the corrosion resistance of sheet iron A. S. Afanas'ev and B. Sh. Shteinberg (*Zhur. Priklad. Khim.*, 1959, **32,** (9), 2046–2056) The corrosion resistance of sheet iron in an atmosphere free from chemically active gases is higher by a factor of 2,5–3,5 than that of roofing steel (0·15%Cu, 0·20%Ni, 0·12%Cr) as established gravimetrically. In an atmosphere contaminated with chemically active gases, both sheet iron and steel are much less resistant but the relative fall in the resistance of iron is appreciably greater.

Experiments on the exposure to tropical conditions of bimetallic couples H. G. Cole (*Corros. Anticorros.*, 1959, **7,** Jan., 3–12) A series of trials on the results of exposure of a number of metals, plated metals, and metal couples to tropical conditions inland and on the coast. Specimens included several mild and alloy steels; the effects of protective coatings were also examined.

The investigation of corrosion failures of ferrous metals E. E. White and K. A. Chandler (*Chem. Ind.*, 1959, Aug. 15, 1028–1035) A general account of corrosive conditions met with and of test methods is given, followed by accounts of actual investigations illustrating exposure to air, fresh water, soil, concrete, sea and river water, and some special cases.

The classical potentiostat: Its application to the study of passivity N. D. Greene (*Corrosion*, 1959, **15,** July, 369t–372t) The practical considerations in designing a potentiostat for the study of the active-passive behaviour of metals are discussed. It is shown that the classical circuit can be improved by reducing the total series resistance and the maximum current output. An improved design with an ultimate potential control of 1 millivolt is described in detail.—J.F.S.

HRE-2 corrosion specimens—blanket region of pressure vessel (loading No.1)—weight data and scale analysis A. R. Olsen (*CF*–58–10–83, 1958, Oct. 31, pp.13; from *Nuclear Sci. Abs.*, 1959, **13,** March 15, 389) Type 347 stainless and Zr and Ti alloys are reported on and scale analyses are discussed.

Studies on the hairline corrosion of varnished steel sheet H. Kaesche (*Werks. Korr.*, 1959, **10,** Nov., 668–681) Hairline corrosion is identified as a special kind of atmospheric corrosion with a preference for varnished steel sheet. In the experiments reported, salt particles were used to accelerate corrosion. The effects of the salt, surface treatment, atmospheric conditions, and varnish thickness were determined; a tentative theory of the causes and kinetics of hairline corrosion was developed.—L.J.L.

Investigating the local and general corrosion for austenitic chromium–nickel steel during thermal treatment and descaling A. V. Shreider, E. M. Kontsevaya, and V. P. Gamazov (*Zhur. Priklad. Khim.*, 1959, **32,** (7), 1509–1515) Specimens of various types of steel were cold rolled after coating with grease to simulate actual conditions. The sulphur content in the grease has been found to cause a great increase in the corrosion of the metal during thermal treatment. The influence of the other components of the grease film have been investigated also and the experiments have shown the electrochemical nature of the process of descaling in alkali nitrate melts.

The pH value determined by those metal corrosion products which are soluble with difficulty N. P. Zhuk (*Zhurn. Fiz. Khim.*, 1958, **32,** (12), 2754–2760) The theoretical pH value for 10 metals which should be given by their difficultly soluble corrosion products (oxides and hydroxides) in non-buffered neutral solutions of salts, in which the interaction of the primary corrosion products does not change by pH any further, was calculated. Two series of experiments were carried out for measuring the pH of a 0·1 M solution of Na_2SO_4 with initial pH values of 5, 7, and 9 and 4, 7, and 10 during the corrosion of the 10 metals in these solutions. The experimental values are mostly in good agreement with the calculated values from the solubility products of these metals.

Investigation of the conditions favourable for the formation and development of pitting in iron T. N. Sharonova, N. I. Fedulova, and A. I. Krasil'shchikov (*Zhurn. Fiz. Khimii*, 1959, **33,** (1), 208–212) The investigation studied the conditions for the appearance of pitting in various aqueous solutions. It was found that the foci of pitting are related to the fluctuations in the potential conditioned by the thermal motion of the molecules and by other causes such as the progress of the diffusion of the electrode processes or the presence of insufficient inhibitors for a complete passivation.

Influence of crystallographic orientation on the pitting of iron in distilled water J. Kruger (*J. Electrochem.Soc.*, 1959, **106,** Aug., 736) Using an Armco iron single-crystal sphere with flats cut parallel to {111}, {110}, and {100} the {110} plane showed the most pits after 3 h. {100} had half and {111} only one-quarter of this number. These values were independent of method of polishing.

Kinetic studies on corrosion systems. I. Polyelectrodes under activation control F. A. Posey (*J. Electrochem. Soc.*, 1959, **106,** July, 571–581) The term polyelectrode is used in this article refers to the situation where more than one chemically distinct individual or partial process is occurring at the same electrode—solution interface. Electrochemical kinetics are applied to the case of corroding polyelectrodes under activation control where rates of partial processes vary over the electrode surface. Kinetics of galvanic couples under activation control are derived, and the uses of steady-state polarizability; potentiostatic, and galvanostatic measurements in the study of polyelectrode systems are outlined (28 refs). **II. The reduction of cupric ion on passive stainless steel electrodes** F. A. Posey, G. H. Cartledge, and R. P. Yaffe (582–589) Experimental techniques and results of tests in an aerated H_2SO_4 medium are described, using potentiostatic, galvanostatic, and tracer methods. The mechanism of the reduction of cupric ion on the oxide surface is discussed (14 refs).

A contribution to the assessment of the suitability of variously treated steel surfaces for protection against corrosion K. W. Sippell and H. Schmidt (*Materialprüfung*, 1959, **1,** 337–352) Tests have been carried out with 11 methods of cleaning the steel surface to determine their effects on three different kinds of surface. It was found that the most frequently used mechanical methods will not always provide a surface suitable for treatment against corrosion. Relatively useful results were achieved with a thermal method.—L.J.L.

Potential studies on passivity to corrosion induced by pretreatment processes. II. Comparative study of chromate treatment and chromate inhibition K. S. Rajagopalan and K. Balakrishnan (*J. Electrochem. Soc.*, 1959, **106,** July, 562–566) The mechanisms of the passivation of Zn by chromate treatment in Cronak (2) and by means of chromate inhibitor are examined and compared by studying potential-time curves of immersion tests in dilute NaCl solution.

T.T.S. diagrams for types 304L and 316L stainless H. F. Ebling and M. A. Scheil (*Met. Progress*, 1959, **76,** Aug., 87–91) The resistance to intergranular attack of three types of Cr–Ni stainless steel is investigated, and time–temperature–sensitization diagrams are constructed, showing the effect of time and reheating or ageing temperature on the corrosion rate in boiling HNO_3.

The action of cathodically evolved hydrogen on iron and nickel as special cases of corrosion-embrittlement of metals M. Smialowski (*Chem. Ind.*, 1959, Aug. 29, 1078–1083) The general phenomena of hydrogen embrittlement and the catalytic effects of S, P, Se, Te, As, and Sb are briefly described. The mechanism of elongation of iron rods and its measurement are considered and theories of the phenomena are reviewed.

Electrochemical and corrosion behaviour of steel and nickel electrodes in sulphuric acid solutions under the action of γ-rays N. Ya. Bune, Ya. M. Kolotyrkin, and G. S. Turikov (*Zhurn. Fiz. Khim.*, 1958, (12), 2679–2685) The effect of the γ-radiation of stainless steels and cast iron corrosion behaviour of 18/8 steel and of nickel in 1 N H_2SO_4 solution under a radiation intensity of $1·5 \cdot 10^{15}$ eV/ml/sec has been investigated. The influence of radiation on the rate of solution depends on the tendency of the metal to passivation. If the effective rate of reduction of the oxidizing components of radiolysis exceeds the passivating current an increase in radiation results in a decrease in the rate of solution (stainless steel). In the opposite case, an increase in the rate of solution is observed (Ni).

The temperature coefficient of the rate of corrosion in the presence of inhibitors I. N. Putilova (*Zhurn. Fiz. Khim.*, 1959, **33,** (1), 226–227) The temperature dependence of the rate of solution of metals in media where H_2 is

evolved is of special importance in the presence of inhibitors. These may be classified into groups according to their influence on *E*. For inhibitors similar in structure and in mechanism of action, *E* is nearly the same.

HISTORICAL

History of die-shaping and forging E. von Wedel (*Stahl Eisen*, 1959, **79,** Oct. 1, 1419–1427) A well illustrated historical review of the die-shaping and forging processes from about 1500 BC to the eighteenth century. As this process was used for minting coins and later in the fabrication of arms it had a particular impact on the historical development of ironwork in general.—T.G.

The location of Byrkeknott, a 15th-century smelting site R. F. Tylecote (*JISI*, 1960, **194,** April, 451–458) [This issue].

BOOK NOTICES

The British Steel Castings Research Association. '*Data Sheets on Moulding Sands*', 2nd ed. 10×8 in., pp.x+45. Illustrated. 1960, Sheffield: The Association. (Price £1 10*s*.)

A second edition of a work first published in 1956 and hitherto restricted to members of the British Steel Castings Research Association, this short book describes the sources, suppliers, and properties of 45 moulding sands (42 of British and three of Belgian origin), with chemical and mechanical analyses. Data on grain shape and refractoriness are given for most sands as well as bonding properties for the naturally bonded ones. Explanatory notes, a map of foundry sand distribution in this country, and a plate showing photomicrographs of typical steel foundry sands provide a useful introduction. Future editions should, however contain an index.—M. L. Pearl.

Brownell, Ll. E. and Young, E. H. '*Process Equipment Design*'. *Vessel Design*. 11×8½ in., pp.xii+408. Illustrated. 1959, New York, London: John Wiley & Sons, Inc.; Chapman & Hall Ltd. (Price £7 16*s*.)

Olszak, W. (Editor). '*Non-Homogeneity in Elasticity and Plasticity*'. Proceedings of the IUTAM Symposium, Warsaw, September 2–9 1958. 10×6 in., pp.xxiv+529. Illustrated. 1959, London, New York: Pergamon Press. (Price £5.)

The first of these books is a comprehensive guide to all aspects of the design of vessels for the process industries. Written for senior and graduate students in engineering, it admirably fulfils its purpose of presenting the many facets of practical design procedure. Throughout the book, basic concepts, industrial practices, and theoretical relationships are woven together in a most instructive manner. All kinds of vessels are discussed, ranging from simple vessels for low-pressure service to thick-walled and multi-layer vessels for high-pressure service. The design of the shells, the bottoms, the roofs, the ended closures, the supports, and the flanges are all discussed in great detail, together with all requisite stress analysis and American standards, codes, and specifications, for components, welding, materials, allowable stresses, etc. Failure criteria are discussed in relation to materials and service conditions. Up-to-date practical and research results are constantly quoted to illustrate and support design methods. Innumerable numerical examples are given. There are even maps of snow loads and seismic disturbances throughout the United States (the reader must supply the UK equivalent!) and the book is profusely illustrated with excellent diagrams and photographs of fabrication procedures and existing installations. It would be difficult to find a more thorough and elegant presentation of theory and research integrated with, and applied to, practice.

The second book is a collection of 52 research papers, mainly theoretical, on problems of hon-homogeneity (at the macroscopic engineering level) and anisotropy of mechanical properties of solids and structural elements. There are sections on elasticity, plasticity, rheology, dynamics, and wave propagation. There are many useful references to work not well known in this country. A survey paper by Professor Olszak and Dr Urbanowski gives a good summary of the extensive work on plastic inhomogeneity carried out mainly in Poland over the last 20 years. The book demonstrates how theoretical mechanics is tending to approach ever more closely to the actual properties of real materials and structures. In doing so new methods of design are emerging, e.g. for minimizing weight or cost, for making the best use of reinforcements, or for taking a realistic account of practical imperfections in any real structure of components. Since these papers represent the growing point of theory in a specialized field of research, and were presented at a meeting of theoreticians, perhaps it is asking too much that many of them should be readily comprehensible to non-specialists. In spite of what is said on the dust jacket there is not much here for physical metallurgists. However theoreticians will enjoy it, and avoiding the more abstruse papers, experimentalists and design engineers will find plenty of ideas worthy of proof, and results worth applying. —A. P. Green.

European Investment Casters' Association. '*Proceedings of the 1959 Conference, Essen, June 1–3, 1959*'. 11½×8 in., [not continuously paginated, ring binding]. 1960, Eindhoven: Philips Gloelampenfabrieken. (Price £2.)

This collection of 14 papers given at the sixth Conference of the European Investment Casters' Association held at Essen in June, 1959, illustrates the problem of producing reports of international conferences in a suitable form within the shortest possible time. On grounds of presentation, the present collection cannot be described as a success. It is published as a book of duplicated papers put together without continuous pagination in a ring binding; there is no contents page or index, half of the papers have not been translated into English and the cost is as high as a properly bound book. The contents, which will be abstracted in part in this *Journal*, are a very mixed bag and range, for example, from a German paper on the Batten-Cordonnier classification system to a British paper on some investment-cast alloys for high-temperature service.—M. L. Pearl.

Harders, F. and Kienow, S. '*Feuerfestkunde. Herstellung Eigenschaften und Verwendung feuerfester Baustoffe*'. 10¾×6½ in., pp.xvi+981. Illustrated. 1960, Berlin, Göttingen, Heidelberg: Springer-Verlag. (Price DM.126.)

This is a remarkable book, not just because it contains 981 pages and is singularly free from errors, but because it succeeds in covering an unusually wide field. Its title, which may be translated, 'Refractories Technology. Production, Properties, and Application of Refractory Building Materials', indicates its scope. Following an opening chapter on test methods and the fundamentals of ceramics, it goes on to deal with each refractory in turn, starting with raw materials and finishing with application. Particularly interesting to the steelman will be the section on casting pit refractories, of which the authors (one of whom—Harders—is Hüttendirektor at Dortmund and the other—Kienow—at the Bergakademie at Clausthal) have clearly made a special study. They suggest for example new techniques for assessing cracking of runner bricks and are able to show a quantitative decrease in such cracking with increasing alumina content. Their studies on the effect of aluminium additions to steel, and in particular on the pick-up of corundum by the glassy lining of the runner brick, will appeal to many technologists over here.

Those who look to the chrome–magnesite or all-basic furnace sections for new information are likely to be disappointed, in that they are surprisingly dependent on British experience. Thus the factors controlling fundamental properties, such as thermal shock resistance and after-contraction, are based on British work, while the explanations given for failure in use, e.g. bursting and flux concentration, are again mostly British and little attempt made to differentiate between major and minor effects. Most interesting to the practical steelman will perhaps be the section on dolomite, which describes German techniques for the manufacture of both unfired and fired bricks and the use of such bricks and large sections in arc furnace side-walls and open-hearth furnaces.

Those who are interested in refractories and can read German are well advised to obtain a copy of this book. Those with more specialized interests may be equally well advised to get appropriate sections translated.—J. H. Chesters

Narayan, P. I. A. and Subrahmanyan, N. N. '*Beneficiation of Low Grade Manganese Ores of India*'. 9½×6½ in., pp.viii+183. Illustrated. 1949, New Delhi: Council of Scientific and Industrial Research. (Price Rs.10=00.)

India is an important supplier of manganese ore to the steel-producing countries of Europe, and to America and Japan, who, in 1956, together absorbed nearly 85% of her exports. Although the reserves of manganese ore in India are very considerable, much of the ore is of too low a grade for metallurgical purposes. Considerable effort has, therefore, been expended on finding ways and means of upgrading the low-grade ores and the results of the investigations, carried out at the National Metallurgical Laboratory, are summarized in this monograph. Three short chapters on the occurrence of manganese ore, on production, export, consumption, and price, and lastly on uses and specifications give a general background to the subject. A short chapter on beneficiation methods introduces the main body of the monograph—beneficiation studies on the Indian ores.

The Indian low-grade manganese ores are classified into four broad groups, viz. simple, ferruginous, garnetiferous, and complex ores, respectively. From the point of view of reserves, the ferruginous ores appear to be the most important. For these ores, a combination of reduction roasting to convert the iron oxides to magnetite followed by low intensity magnetic separation is recommended. For the simple ores, straightforward gravity methods are generally sufficient to remove the gangue minerals, while for the garnetiferous ores, electrostatic separation was most successful. The complex ores require a combination of methods and in general produced lower grade concentrates which would need to be blended with high grade ores to satisfy commercial specifications. The monograph contains a wealth of detail—almost too much—on individual ore-testing investigations and it is not easy from all this information to assess the relative importance of the various low grade ore types in relation to the country's ore reserves and to their subsequent economic exploitation. The last chapter summarizing the investigations could well have dealt more fully with these aspects. Nevertheless, a great deal of valuable work has been reported, and this monograph should be a useful addition to the literature on manganese ore concentration. —G. E. Davies.

Seymour, R. B. '*Hot Organic Coatings*'. With a special chapter by G. B. McComb. 9×6 in., pp.ix+233. Illustrated. 1959, New York, London: Reinhold Publishing Corporation, Chapman and Hall Ltd. (Price £3.)

The author has produced a manual which emphasizes the practical rather than the theoretical aspects of organic coatings in the hot-melt state and in hot solution. The book provides data on physical properties together with chemical-resistance characteristics. Among the coating materials discussed are Asphalt and Related Minerals,

Coal-Tar Pitch, Petroleum Waxes, Synthetic Hydrocarbon Resins, Cellulose Derivatives, and Natural Waxes. Base materials which are described include Metals, Textiles, Wood, Paper, and Concrete. Although it is almost exclusively confined to American sources, practices, and trade names, the book will be useful to corrosion engineers and to finishing and packaging departments in many industries.

VIEREGGE, G. '*Zerspanung der Eisenwerkstoffe*'. Stahleisen-Bucher Band 16. 9×6½ in., pp.xii+346. Illustrated. 1959, Düsseldorf: Verlag Stahleisen m.b.H. (Price DM.40. .)

This book is devoted to a study of the machining of steels and cast iron and is divided into three sections that cover the principles of metal cutting, machinability, and materials for the production of cutting tools, respectively.

It is a very good book but many of the compound words that are used will not be found in any dictionary: the book, however, provides its own dictionary and if it is read carefully with reference to the diagrams it is improbable that misunderstandings will arise. In some cases, words that to an Englishman may appear to be very similar have completely different meanings. For instance in the first section the author uses the words 'Spanungsdicke' and 'Spandicke'; reference to Fig.8, p.6 shows that the former means 'depth of cut' and the latter 'chip thickness'. The first section is divided into eight sub-sections which deal with different aspects of the fundamentals of cutting and all of them are well worth careful study. Of these the three that are particularly interesting are B, E, and F that deal with chip formation, damage of cutting edges, and wear of cutting tools and durability. It is only unfortunate that although the author classifies grinding as a machining operation he has not dealt with it although he deals at length with the action of twist-drills and milling cutters. The second main section dealing with machinability is divided into six sub-sections the first two of which are devoted to the fundamentals of machinability and the remaining four to the machinability of structural and tool steels, steel castings, heat and acid resisting alloys, and cast iron, respectively. The final section is devoted to a consideration of materials used for cutting tools, namely, unalloyed tool steels, alloyed tool steels (among which the author places high-carbon–chromium non-distorting tool steels and steels containing up to 7½% tungsten), high-speed steels, Stellite and other hard alloys, hard metals, i.e. sintered tungsten carbide and the like, diamond cutting tools, sintered oxides, and cutting tools made from carbides, borides, nitrides, and silicides.

Numerous analyses are given, mostly of steels used in Germany, and it is rather surprising to note that German high-speed steels usually contain not more than 18% tungsten whereas in this country up to 24% tungsten is frequently used. Besides dealing with the effect of composition the author deals in a masterly way with the effect of micro-structure. The book is amply illustrated with excellent diagrams and cannot be too highly recommended to anyone interested in machining and machinability.

—J. F. KAYSER.

NEW PUBLICATIONS

These titles are also available on index cards in advance of publication in the Journal, *each title being classified under the Universal Decimal system (UDC). Details and subscription rates can be obtained from the Secretary, The Iron and Steel Institute.*

AKADEMIYA NAUK, SSSR. Institut Mashinovedeniya. [Academy of Sciences, USSR. Institute for the Study of Machines.] '*Povyshenie effektivnosti tormoznykh ustroistv. Svoistva friktsionnykh materialov.*' [*Increasing the efficiency of braking equipment. Properties of friction material.*] [In Russian.] 10½×6¾ in., pp.184. Illustrated. Moscow, 1959: The Academy. (Price 9r. 50k.)

AKADEMIYA NAUK, SSSR. Institut Metallurgii Imeni A. A. Baikova. [Academy of Sciences, USSR. A. A. Baikov Institute of Metallurgy]. '*Teplovye protsessy pri Kontaktnoi svarke. Sbornik trudov Laboratorii Svarki Metallov.*' [*Thermal processes in contact welding. Collection of papers from Laboratory of Metal Welding.*] [In Russian.] 10½×6¾ in., pp.278. Illustrated. Moscow, 1959: The Academy. (Price 16 r.)

AMERICAN SOCIETY FOR TESTING MATERIALS. '*Symposium on Electroless Nickel Plating (Catalytic Deposition of Nickel–Phosphorus Alloys by Chemical Reduction in Aqueous Solution*'). Sponsored by Section C on Electroless Nickel, of Subcommittee I on Specifications, Papers, and Definitions, of Committee B–8 on Electro-deposited Metal Coatings. S.T.P. No.265. 9×6 in., pp.67. Illustrated. Philadelphia, 1959: The Society. (Price, Members $2.00; Non-Members $2.50.)

AMERICAN STANDARDS ASSOCIATION. '*American Standards*, 1959, *Price List and Index*'. 11×8½ in., pp.66. New York, 1960: The Association.

AVERBACH, B. L., FELBECK, D. K., HAHN, G. T., and THOMAS, D. A. (Editors.) '*Fracture. Proceedings of an International Conference on the atomic mechanisms of fracture held in Swampscott, Mass., April 12–16, 1959*'. Technology Press Books in Science and Engineering. 9×6 in., pp.xvii+646. Illustrated. New York, London: 1959: The Technology Press of Massachusetts Institute of Technology, John Wiley & Sons, Inc., Chapman & Hall Ltd. (Price £7.)

BAILEY, A. R. '*A Text-Book of Metallurgy*.' (2nd ed.) 8½×5½ in., pp.x+561. Illustrated. London, 1960: Macmillan & Co. Ltd. (Price £1 10*s*.)

BRITISH COAL UTILISATION RESEARCH ASSOCIATION. '*Bibliography of Publications* 1938–1959'. 10½×8¼ in., pp.49. Leatherhead, 1960: The Association. (Price 5*s*.)

BRITISH STEEL CASTINGS RESEARCH ASSOCIATION. '*Data Sheets on Moulding Sands*'. (2nd (revised and enlarged) ed.) 10×8 in., pp.x+45. Illustrated. Sheffield, 1960: The Association. (Price £1 10*s*.)

CLOUGH, W. R. (Editor.) '*Reactive Metals*'. Proceedings of the Third Annual Conference sponsored by Niagara Frontier Section in Co-operation with The Metallurgical Society, American Institute of Mining, Metallurgical and Petroleum Engineers, Buffalo, New York, May 27–29, 1958. Metallurgical Society [of the AIME] Conferences series. Volume 2. 9×6 in., pp.xiv+610. Illustrated. London, New York, 1959: Interscience Publishers. (Price £5 13*s*.)

DICKMANN, H. '*Aus der Geschichte der deutschen Eisen- und Stahlerzeugung*'. 2. Auflage. Monographien über Stahlverwendung. 9½×8 in., pp.101. Illustrated. Düsseldorf, 1959: Verlag Stahleisen. (Price DM.4.50.)%

ENGINEERING MATERIALS AND DESIGN. '*Engineering Materials and Design Conference. 22nd–26th February 1960, London. Papers*'. 13×8 in. [not continuously paginated], 21 papers. London, 1960: 'Engineering Materials and Design'.

EUROPEAN INVESTMENT CASTERS' ASSOCIATION. (*Proceedings of the [6th] Conference, Essen, June 1st–3rd, 1959*. 11½×8 in. [not continuously paginated], 14 papers, duplicated, ring binding. Eindhoven. Philips Gloelampenfabrieken. (Price £2.)

JASTRZEBSKI, Z. D. '*Nature and properties of Engineering Materials*'. 9×6 in., pp.xvii+571. Illustrated. New York, London, 1959: John Wiley & Sons, Inc., Chapman & Hall Ltd. (Price £4 8*s*.)

KUTATELADZE, S. S., BORISHANSKI, V. M., NOVIKOV, I. I., and FEDYNSKII, O. S. '*Liquid–Metal Heat Transfer*'. Translated from Russian ['*Zhidkometallicheskie Teplonositeli*']. Supplement No.2 of *Atomnaia Energiia*, 1958. 10¾×8½ in., pp.i+149. Illustrated. New York, London, 1959: Consultants Bureau, Inc., Chapman & Hall Ltd. (Price £9.)

LEYMONIE, C. '*Les Traceurs Radioactifs en Métallurgie Physique*'. Preface de P. Lacombe. 8½×5½ in., pp.xvi+221. Illustrated. Paris, 1960: Dunod. (Price 32 NF.)

LINDSAY, R. W. (Editor.) '*Quality Requirements of Super-Duty Steels*'. Proceedings of a Technical Conference sponsored by Physical Chemistry of Steelmaking Committee of the Iron and Steel Division, The Metallurgical Society, and Pittsburgh Section, American Institute of Mining, Metallurgical and Petroleum Engineers, Pittsburgh, Penn., May 5–6, 1958. Metallurgical Society [of the AIME] Conferences series. Volume 3. 9×6 in., pp.x+309. Illustrated. London, New York, 1959: Interscience Publishers. (Price £3 4*s*.)

METALLURGICAL ENGINEERS LTD. REKUPERATOR KG. DR. ING. SCHACK & CO., SETREM, and THE GRISCOM-RUSSELL SCHACK CO. INC. '*Papers and discussions presented at the Second Recuperator Conference, Paris, 24th and 25th April 1959*'. [Papers by K. Schmitz, S. H. Brooks, J. F. Whitfield, F. Rivalta, K. B. Ria, H. Reinfeld, D. Petit, T. E. Dixon, and H. A. Kühne, X. Trevoux.] 11¾×8½ in., pp.61+28. Illustrated. London, 1960: Metallurgical Engineers Ltd.

PROCKTER, C. E. (Editor.) '*Kempe's Engineers Year-Book for 1960*'. 2 vols. 7×4¾ in., pp.xv+1324, ix+1414. Illustrated. London, 1960: Morgan Brothers (Publishers) Ltd. (Price, 2 vols. in case, £4 7*s*. 6*d*.)

ROBERTS, D. A., ROACH, D. B., and HALL, A. M. '*Physical and Mechanical Properties of Nine Commercial Precipitation-Hardenable Stainless Steels*'. PB 151068. 10½×8 in., pp.13+64. Illustrated. Washington, 1959: Office of Technical Services (Price $2.25.)

ROOS, A. '*Technique Metallografique*'. Préparation des surfaces métalliques pour micrographie et macrographie. 8½×5¼ in., pp.vii+121. Illustrated. Paris, 1960: Dunod. (Price 13.50 NF.)

STEIBER, J. '*The Steel Industry Wage Structure*'. A study of the Joint Union–Management for Evaluation Program in the Basic Steel Industry. Wertheim Publications in Industrial Relations. 9½×6½ in., pp.xi+379. Cambridge, Mass., London, 1959: Harvard University Press, Oxford University Press. (Price £3 4*s*.)

STICHTING CENTRUM VOOR LASTECHNIEK. STUDIECENTRUM VOOR SCHEEPSBOUW EN NAVIGATIE. [Netherlands Centre for Welding Technique. Netherlands Centre for Shipbuilding and Navigation]. '*Guide to the Collection of Imperfections in Butt-welded Joints*'. [Instruction Manual for use with set of 56 cards supplied in steel filing box; text of manual and cards in English, French, German, and Spanish.] 8×5¾ in., pp.92. Haarlem, n.d.: De Technische Uitgeverij H. Stan N.V. (Price-set of cards—Dutch Guilders 250.–.)

TSENTRAL'NYI NAUCHNO–ISSLEDOVATEL'SKII INSTITUT CHERNOI METALLURGII (TsNII–ChM) INSTITUT METALLOVEDENIYA I FIZIKI METALLOV. [Central Scientific Research Institute of Ferrous Metallurgy Institute of Metallography and the Physics of Metals.] Lyubov, B. Ya. (Editor.) '*Problems of Metallography and the Physics of Metals*'. [Translated from the Russian '*Problemy Metallovedeniya i Fiziki Metallov*', Chetvertyi Sbornik Trudov. (Fourth Collection of Works), Moscow 1955.] 10½×8¼ in., pp.476. Illustrated. New York, London, 1959: Consultants Bureau, Inc., Chapman & Hall Ltd. (Price £3 16*s*.)

UNITED STATES ARMED SERVICES TECHNICAL INFORMATION AGENCY. '*Correlation Index of Technical Reports. (AD–PB Reports)*'. PB 151567 S. 10½×8 in., pp.184. Washington, 1958: Office of Technical Services. (Price $3.00.)

VEREIN DEUTSCHER EISENHÜTTENLEUTE V.D.Eh.) '*Förderung von Forschung und Lehre auf dem Gebiete des Eisenhüttenwesens durch den Verein Deutscher Eisenhüttenleute*'. [Reprints of articles from *Archiv für das Eisenhüttenwesen* and *Stahl und Eisen*, 1957–1959.] Band II. 11½×8 in., iv+66 reprints not continuously paginated. Illustrated. Düsseldorf, 1959: Verlag Stahleisen.

'WIRE INDUSTRY' LTD. '*The 1960 Wire Industry Encyclopaedic Handbook*'. 8½×5½ in., pp.532. Illustrated. London, 1960: The Wire Industry'. (Price £1 5*s*.)

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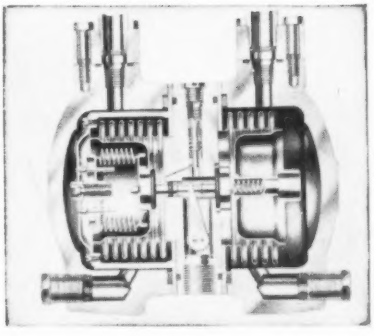

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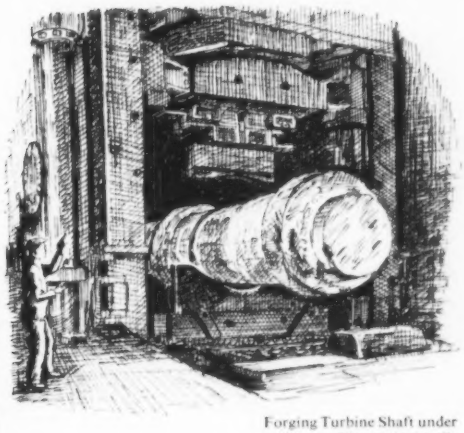
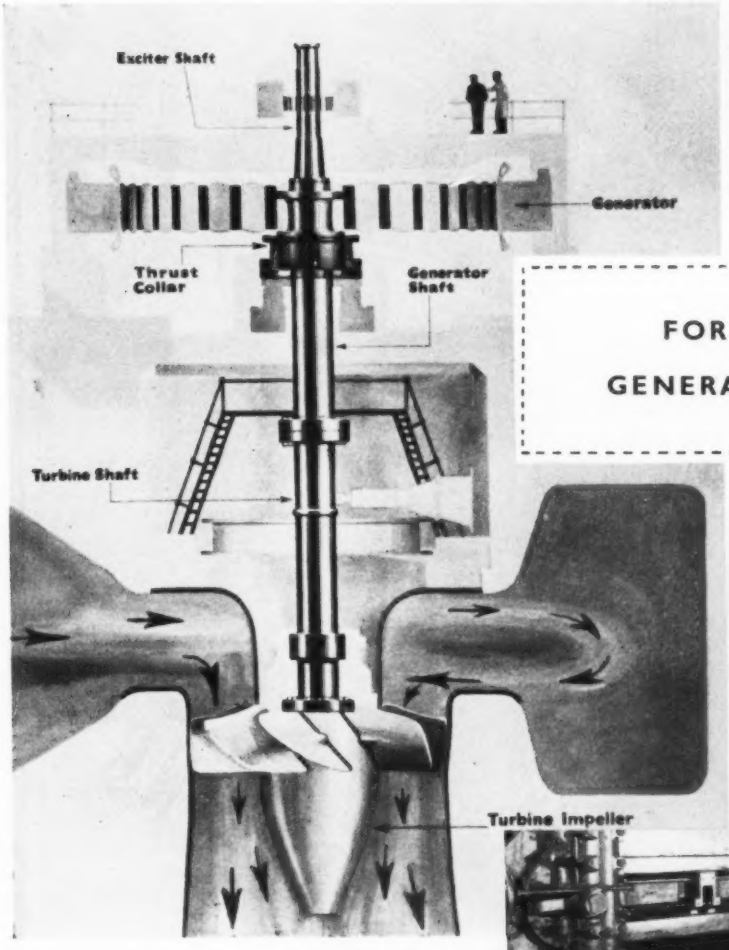


Forging Turbine Shaft under 7,000 ton Electro-hydraulic Press.



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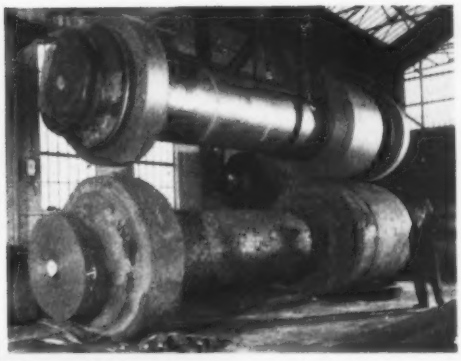
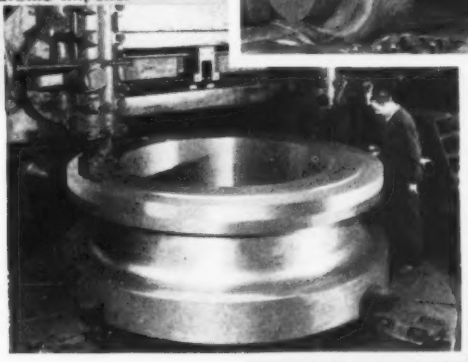
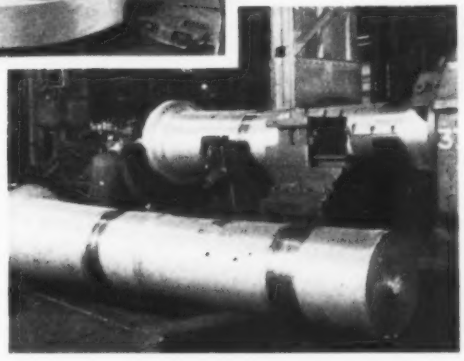


Rough machined and black forged steel Turbine Shafts, 22' 11" long.



Machining forged steel Thrust Collar, weight 18½ tons.

Forged steel Exciter Shafts, each weighing 8½ tons.



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ferro-manganese gas from blast furnaces

The photographs reproduced above show the three Holmes-Elex Electrical Precipitators cleaning ferro-manganese gas after the blast furnaces at the works of the Workington Iron & Steel Company (Branch of the United Steel Companies Limited). This installation has a total capacity of 4,200,000 c.f.h. at N.T.P.

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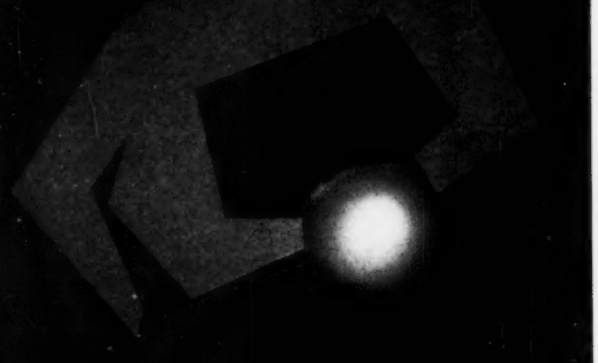

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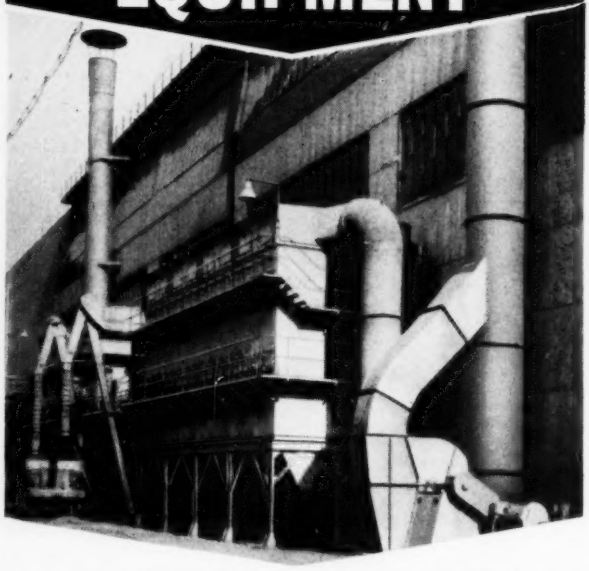

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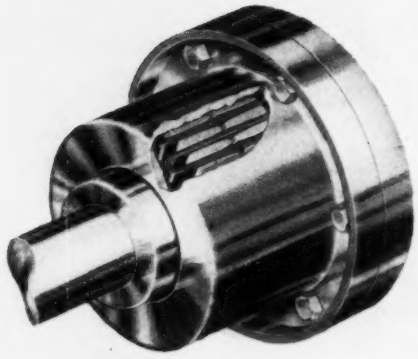

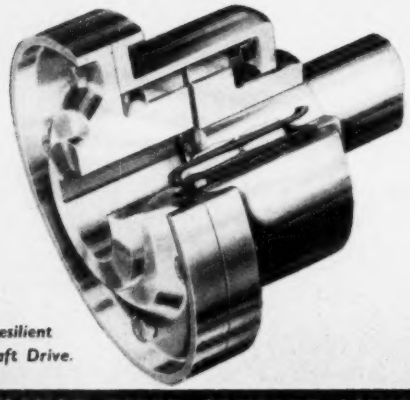

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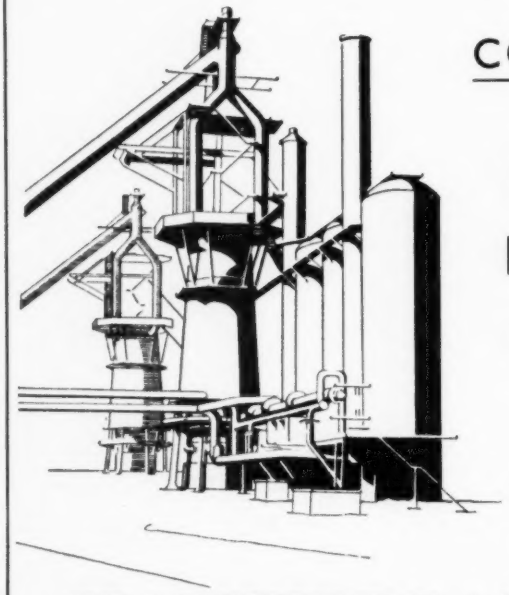

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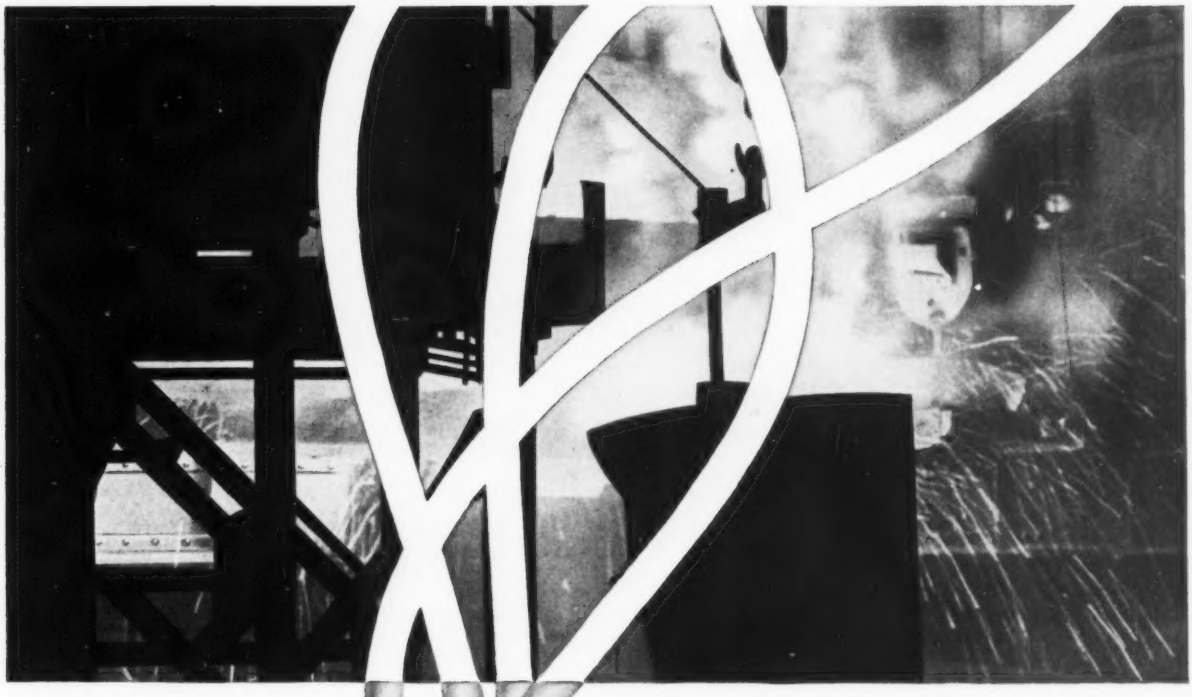

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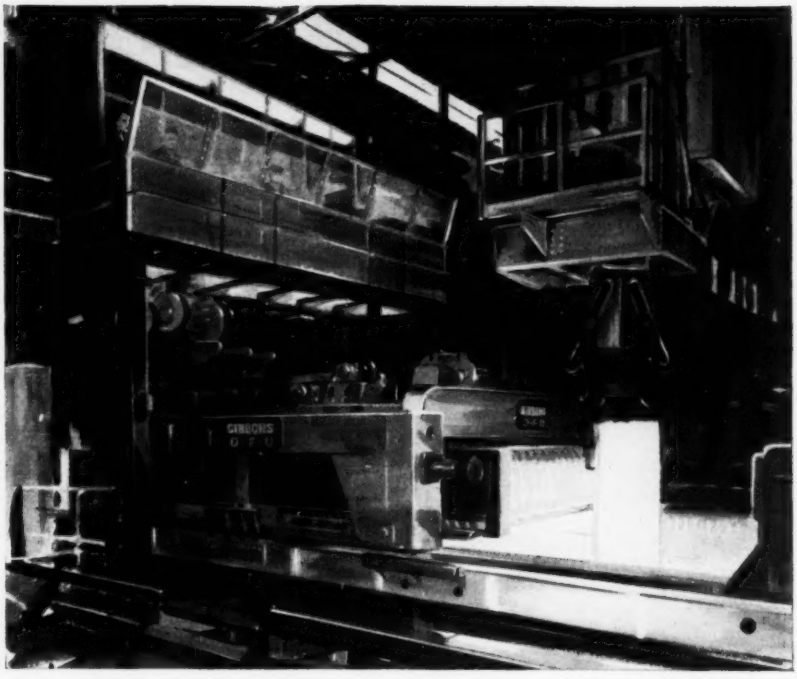

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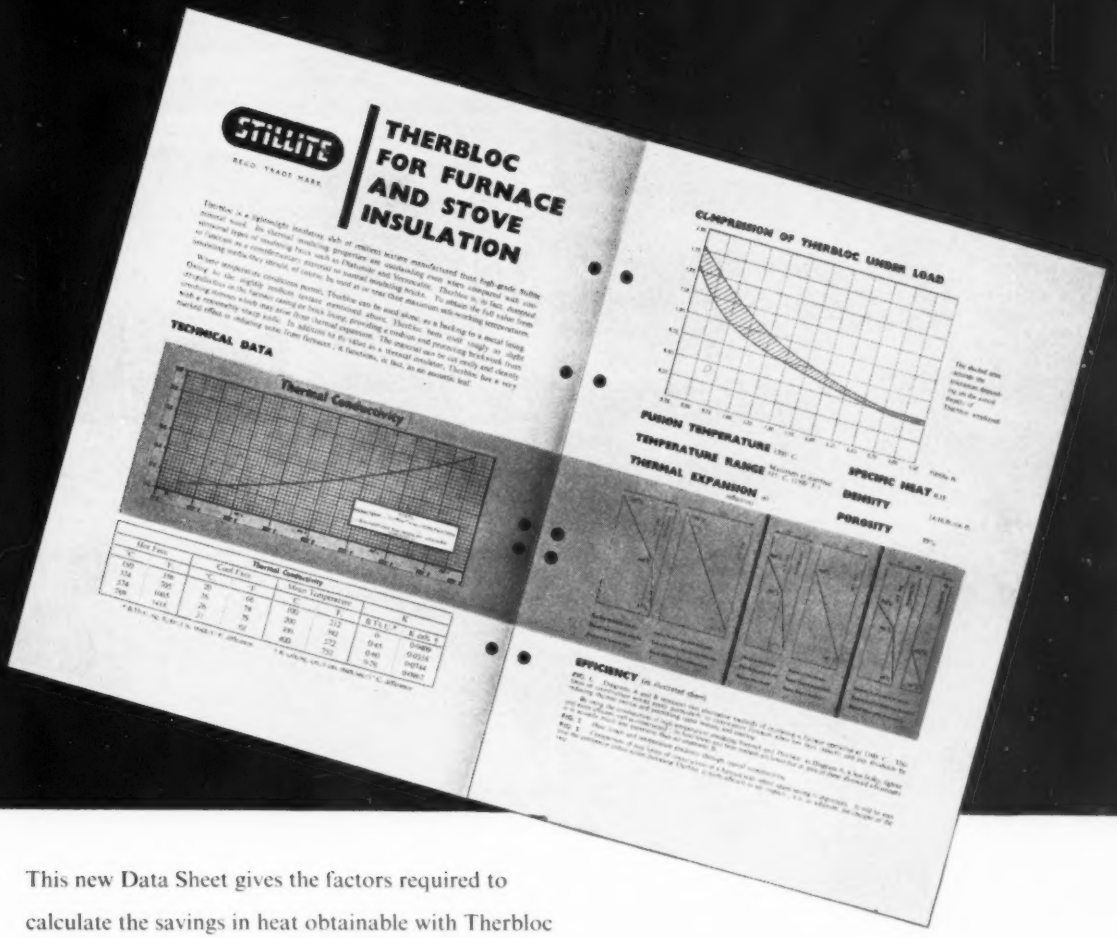

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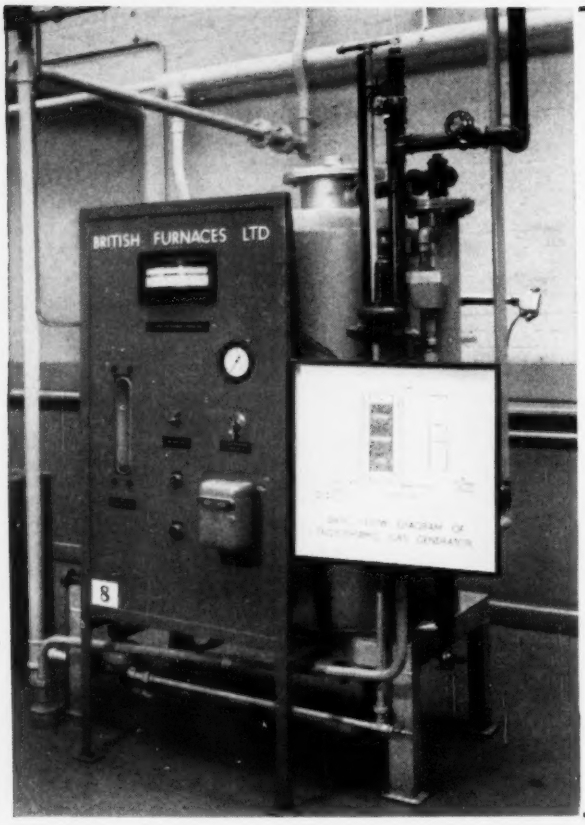

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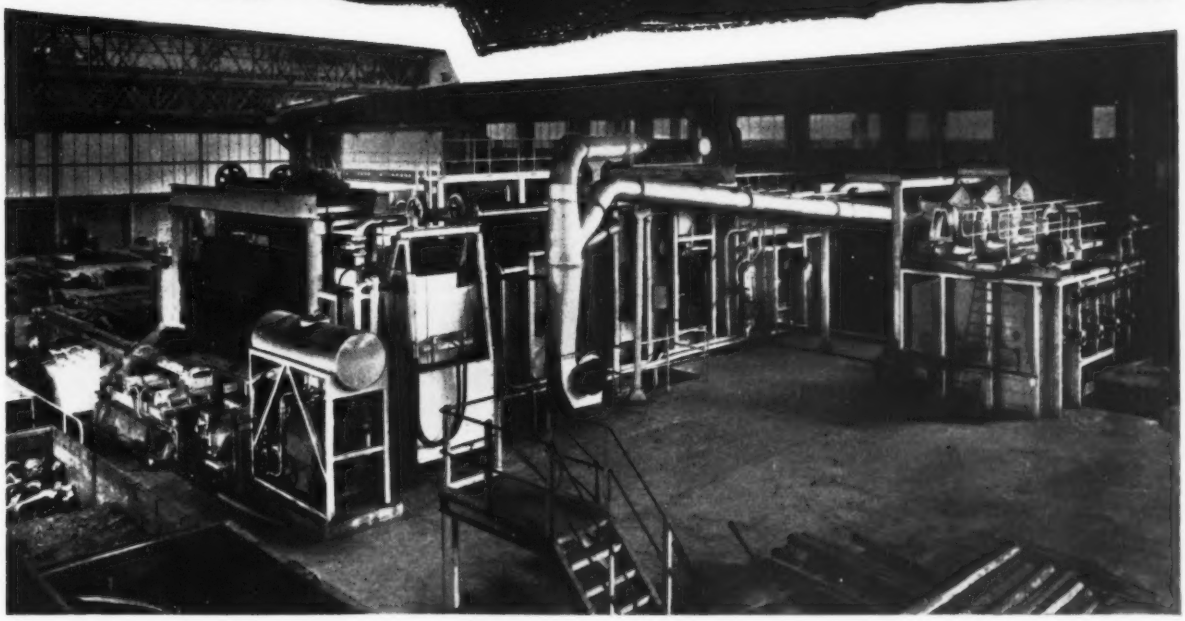

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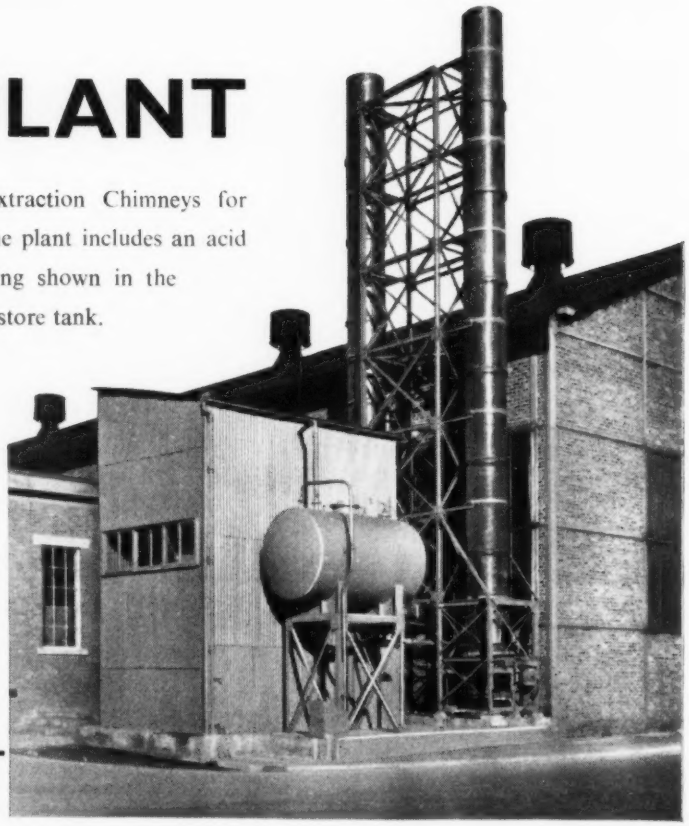
PICKLING PLANT

A typical arrangement of Keebush Fume Extraction Chimneys for extracting fumes from a tube pickling plant. The plant includes an acid recovery section which is housed in the building shown in the foreground. Also shown is a bulk sulphuric acid store tank.



For further details of complete pickling plant and processes please write to—

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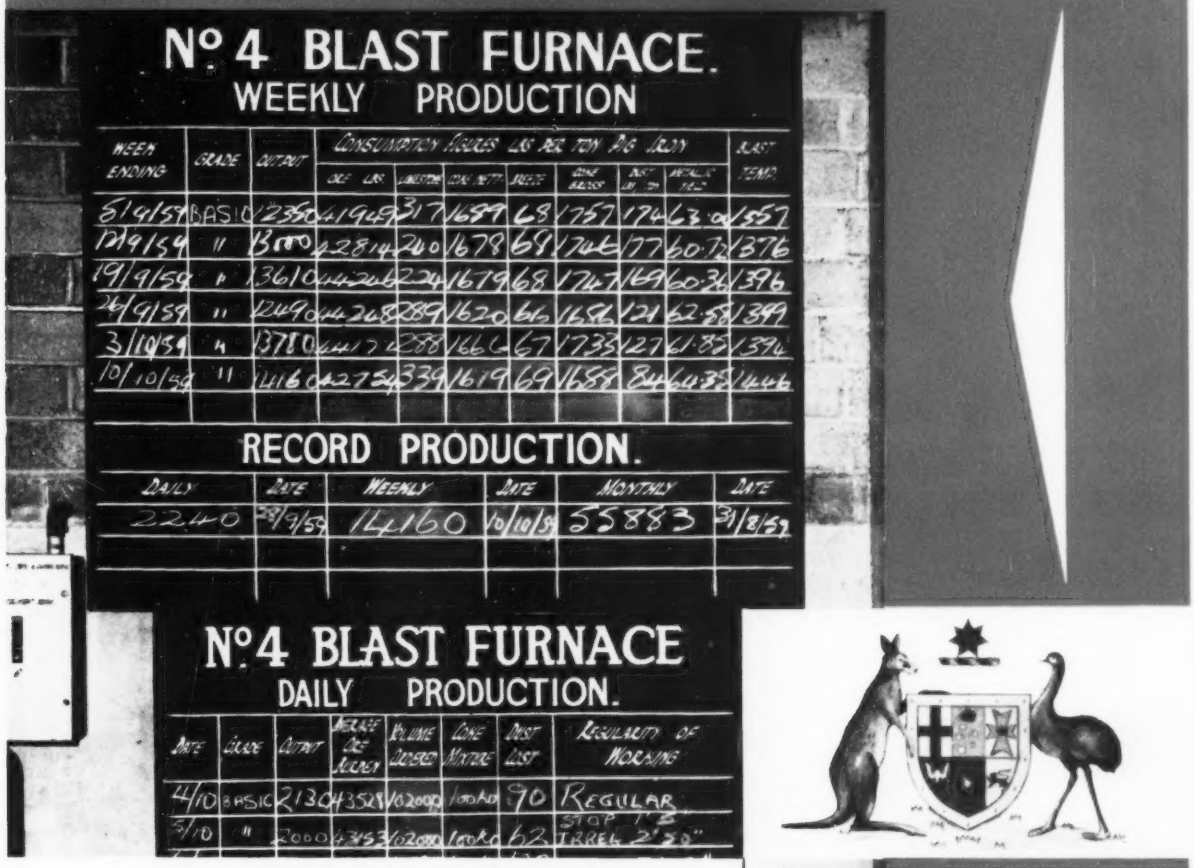

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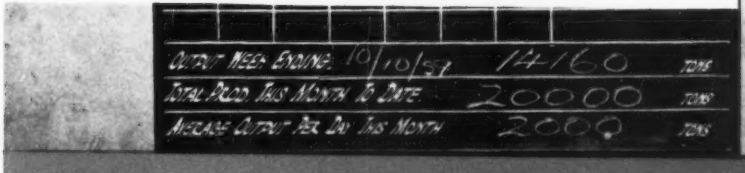
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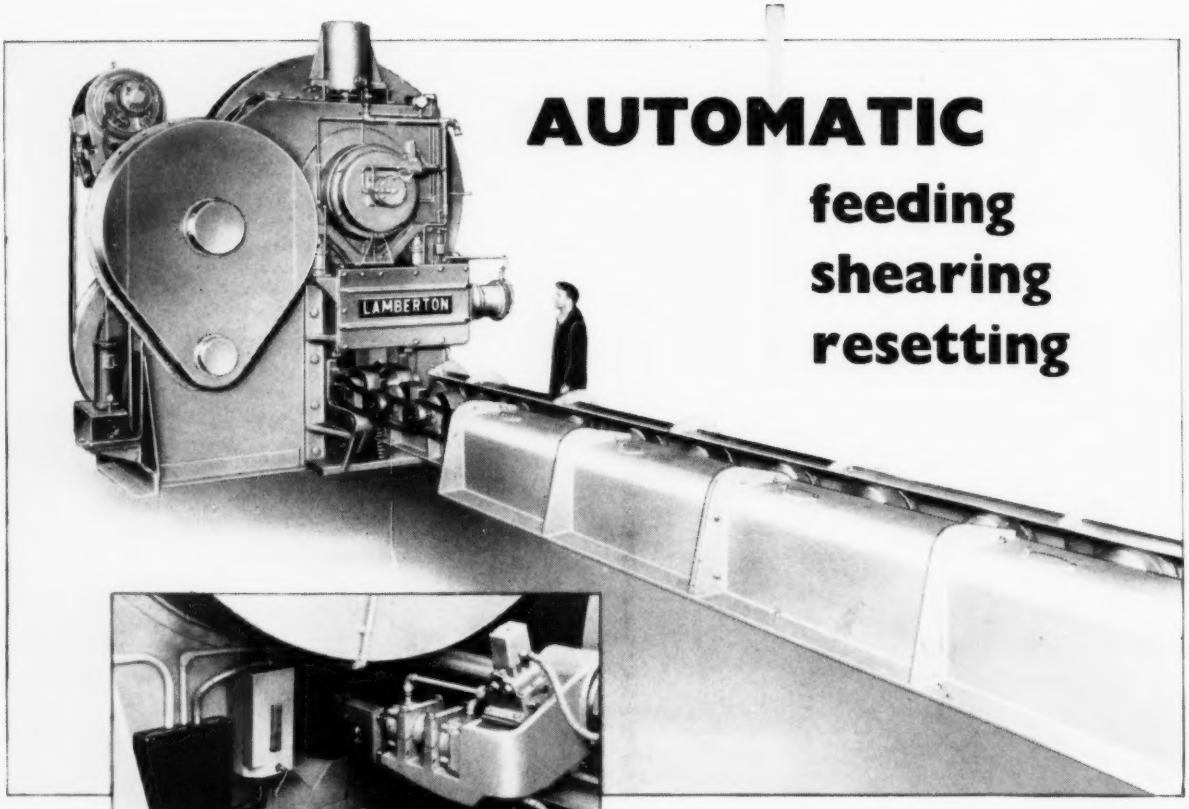

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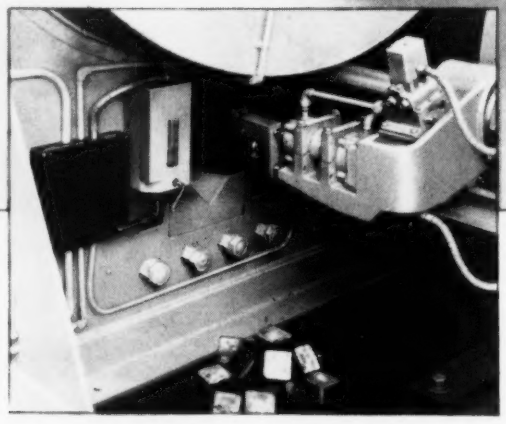

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